

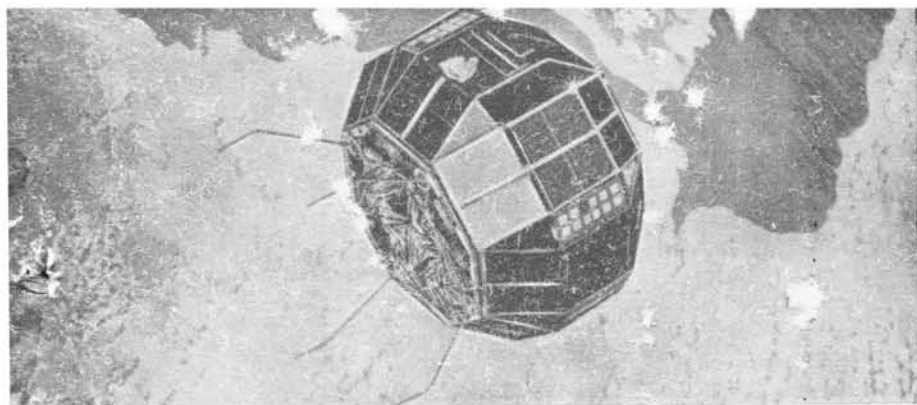
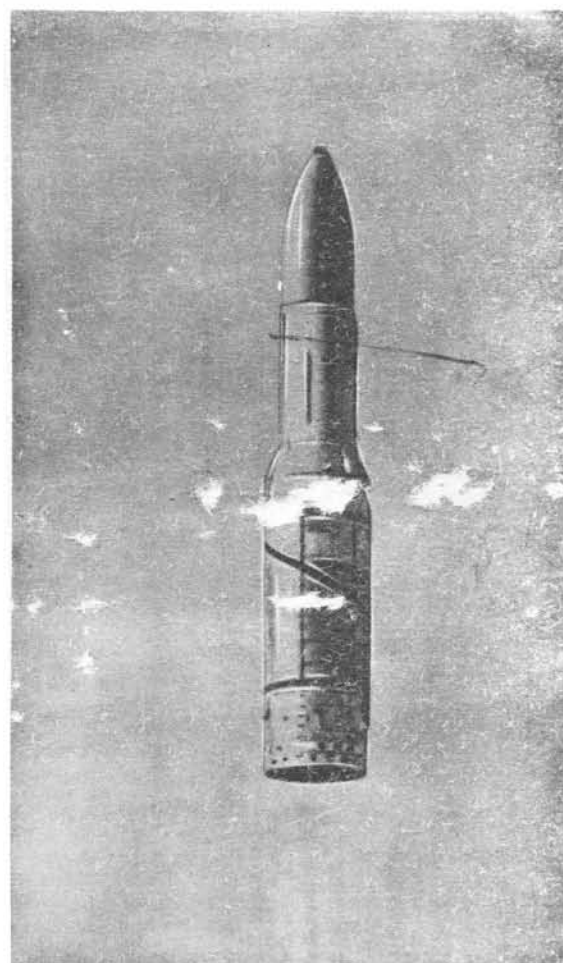
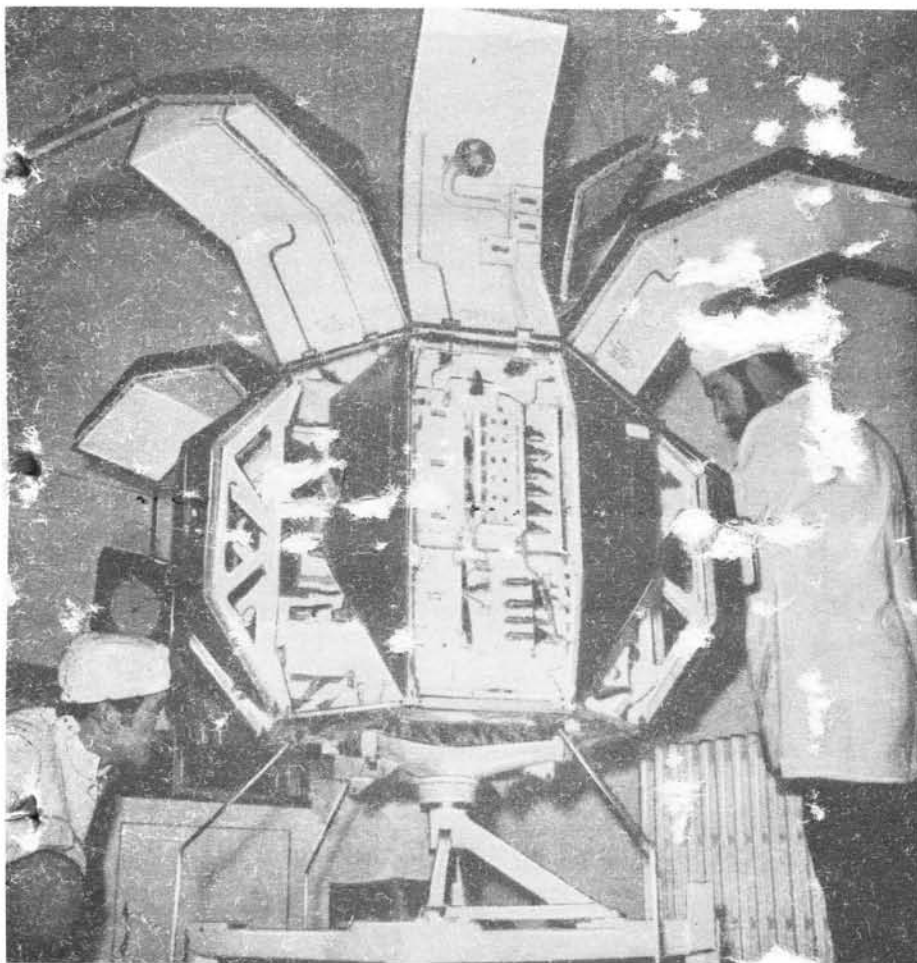
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КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-1

(спейсфлайт)
По подписке 1972 г.

SPACEFLIGHT

Volume 14 No 1 January 1972



Published by The British Interplanetary Society

PATRICK MOORE

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EQUIPMENT APPEAL FUND

We should like to thank those members who have already responded to the President's letter appealing for funds to help the Society purchase composing and printing equipment.

A target of £5,000 has been set. Within the first few weeks donations totalled £300.

Each member should be concerned to see that we reach our target, and help to contain the level of ever rising costs.

If you have not already done so, will you please contribute now, and generously. Your donation is badly needed and will be most welcome.

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COVER

PROSPERO IN ORBIT. Britain's first satellite launched by independent effort has proved a great success. It has been sending a stream of information on the function of a new PCM telemetry system, power supplies, solar cells, protective finishes, and the impact of micro-meteoroids. This data will now be applied in the design of new space systems to help industry keep abreast of a highly specialised international market. *Left*, Prospero undergoes final checks by BAC at Bristol before being sent to Woomera. Note the ease of access to equipment. *Right*, launching was made on 28 Oct. 1971 by Black Arrow R.3, the last rocket of the series. The launcher was cancelled in July as part of a Government review of British space effort. *Below*, an artist's impression of Prospero in orbit. The 66 kg spin-stabilised satellite is 71 cm long by 109 cm diameter. Planned active life is 6 months to 1 year.

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 14 NO 1 JANUARY 1972

MILESTONES

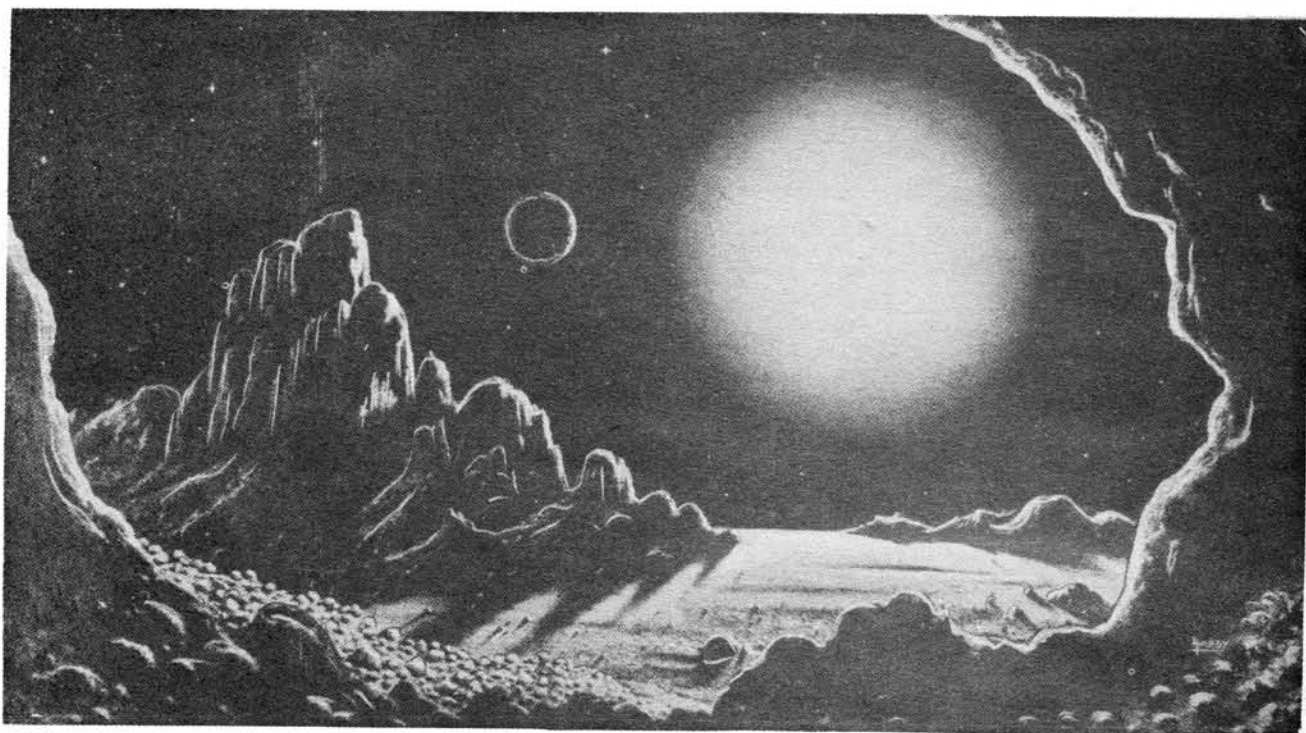
October

- 8 UK-4 scientific satellite flown from London Airport to US by BOAC for launching late November by NASA Scout from Western Test Range, California.
- 11 Soviet ground station commands destruction of Salyut 1 by a retro-burn causing orbital station to re-enter atmosphere over Pacific Ocean. Lifetime in orbit 175 days. Natural decay was predicted by RAE for 10 Nov.
- 14 NASA confirms launch date of Apollo 16 as 17 Mar. with lift-off scheduled for 1303 hrs. EST (1803 hrs. GMT). Destination is Descartes central highland region of Moon.
- 16-29 Ten-man NASA team visits France, Italy, West Germany, Britain, the Netherlands and Belgium to review European-sponsored research on the space shuttle.
- 22 NASA announces that a second mid-course correction to the Mariner 9 spacecraft is unnecessary. Second mid-course adjustment was tentatively scheduled for 26 Oct, but months of tracking revealed that flight path was sufficiently precise for the Mars orbit insertion manoeuvre on 13 Nov.
- 28 Britain becomes 6th nation - after the Soviet Union, United States, France, Japan and China - to achieve orbit by independent effort. Launched at 0409 GMT, Black Arrow R.3 placed the 66 kg Prospero (X-3) technology satellite into an orbit ranging between 537 and 1,593 km inclined at 82 deg. to the equator. Built by BAC and Marconi Space and Defence Systems at cost of about £2 million, Prospero is designed to test new satellite equipment including PCM telemetry, power supplies, solar cells and protective finishes. A micrometeoroid experiment was supplied by Birmingham University.
- 28 UK Ministry of Defence procurement executive on behalf of Department of Trade and Industry, places £3 million contract with Hawker Siddeley Dynamics for development of 87 kg three-axis stabilised X-4 technology satellite. Main sub-contractors are Marconi Space and Defence Systems, Ferranti and Solartron. Launch is scheduled by NASA Scout from the Western Test Range, California, into 500 km Sun-synchronous orbit in 1974.

November

- 2 NASA announces that Mariner 9 may have been struck by meteoroid on final leg of its journey to Mars but attitude problem is traced to fault in a navigational instrument which is subsequently corrected.
- 5 Europa II (F.11) launched from Kourou, French Guiana, at 1300 hrs. GMT fails to achieve orbit. Vehicle broke up at altitude of about 54 km some 150 sec. after lift-off before the point of first stage separation. Main debris fell into the Atlantic about 407 km downrange.

Cover Photo: British Aircraft Corporation and Department of Trade and Industry



An imaginary landscape of a hypothetical planet of the binary α Herculis, illuminated by the red supergiant component. The distant green companion (out of picture) tinges the shadow side of the mountains and gives a double phase to a moon in the black sky. This picture, by BIS-member David Hardy, FRAS, is available as a fine-art colour reproduction 20-in. by 36-in. direct from Astro-Art The Hollies, Low Road, Haddiscoe, Norwich, NOR 29W, England, price £2-65.

ASTROGENIC ENVIRONMENTS: THE EFFECT OF STELLAR SPECTRAL CLASSES ON THE EVOLUTIONARY PACE OF LIFE

By Krafft A. Ehricke*

Introduction

As a human endeavour, interstellar flight may find its crowning experience in linking 2 intelligent species over cosmic distances. A mission to an alien civilization will almost certainly be preceded by, hence stimulated by, radio contact or by a visit to our Solar System by members or cybernetic explorers of their community. For this reason, as well as for general reasons, the question of where in the vastness of the surrounding star streams a sister civilization might be found with somewhat higher than average probability is of continuing interest.

At the lowest level of specificity is the general statistical argument that if among the 100,000 million stars of our galaxy a 'reasonable' percentage, say 1-10%, have planets with intelligent life, our galactic intelligence community must number between 1,000 and 10,000 million. This gives us very little to go by.

Dyson [1] suggests a search for infrared energy sources on the basis that highly advanced civilizations might have modified their solar system to the extent of surrounding their star entirely with planetary matter at an environmentally suitable distance, so as to fully utilize their star's entire energy output. Project Ozma's radio search [2], besides having been limited to a range of less than 20 light years,

was guided by the criterion of stellar similarity to our Sun. Sagan and Shkolovskii [3] speculated quite thoroughly on the possibility that Earth may have been visited by (interstellar) space travellers several millennia ago.

Still, we are left with very little to go by in searching for likely, rather than possible, locations of galactic sister intelligences. The question must be attacked from every possible angle and very few of these have been exhausted. A new approach, based on the concept of stellar characteristics as bio-evolutionary drivers, is discussed here.

Astrogenic and Planetogenic Environments

Discussions of galactic life forms are commonly prone to be short-circuited by the temptation to speculate on non-carbonaceous (e.g. silicon-based) life. Yet, unless the laws of physics, chemistry and biocybernetics are suspended elsewhere, no chemical element offers even remotely as stable a base for living matter, especially intelligent life, as does carbon. Therefore, at the risk of being parochial, only carbonaceous life will be considered here, not only because

* Chief Scientific Advisor, Advanced Programs, Space Division of North American Rockwell, Downey, California.

it is the most likely form, but also because it is the only one about which we have any information.

Secondly, it is appropriate (fig.1) to distinguish 3 planetary macro-climates, which we will designate as lunar, terrestrial and abyssal, and a 4th (open space) which is presently of lesser relevance. The surfaces of Mercury, Mars and asteroids resemble lunar conditions in terms of sub-gravity, low or negligible atmospheric pressure, cratered, arid surface and great temperature extremes between day and night. At least 2, if not several of these factors combine in either of these lunar environments to apparently prohibit the emergence of life. In the abyssal category, we can distinguish between the pyro-abyssal (Venus) and the cryo-abyssal variety (Jovian planets). At least on Jupiter, however, the core region must be classified as pyro-abyssal, so that an intermediate layer in the biologically bearable pressure region can be postulated in which the physical conditions could permit the rise of life. This layer constitutes an important sub-category to which we will refer as Jovian environment and potential biota as *abyssal life*.

We are reasonably certain that the formation of the complex precursor molecules of life, and primordial life itself, require a reducing environment. Both primordial terrestrial and Jovian environments meet this condition. On a Jovian-sized planet, billions of chemical reactions must take place for every reaction in the primordial environment of a terrestrial planet (0.1 to 10 times Earth's mass). The Jovian environment, therefore, may very well produce abiotic hydrocarbons (precursor molecules (formaldehyde) and organic molecules (carboxylic and amino acids, porphyrins and porphyrans) at a sufficient rate to sustain anaerobic life at least on the bacterial (autotrophic, heterotrophic) level for an indefinite period, powered by its own internal energy sources. The planet need not be located in the star's ecosphere (cf. below), and the Jovian environment is such that its potential biota cannot and need not establish a direct linkup with solar (or stellar) energy. In this sense, we can define life in the Jovian as *planetogenic*, or *star-independent*.

By contrast, terrestrial life (except for the small abyssal enclave at great ocean depths) is life at the fringes of space (*fringe life*). On our terrestrial planet, life arose only as an indirect consequence of solar energy. But, being far below Jovian size, purely terrestrial resources could not sustain planetogenic life beyond the bacterial stage, and even that only for a very limited period of perhaps not more than 10-50 million years. Therefore, life would have been a very transient, and long past, phenomenon on this planet some 3,000 million years ago, had it not been for the capability of the photo-autotrophs to break out of the planetogenic confinement and link life's processes to the energy of sunlight. Primitive beginnings eventually culminated in the evolution of the chlorophyll molecule, the basic solar-powered motor of life. By availing itself of an extraterrestrial resource, life overcame its First Great Crisis (we are presently in the Second Great Crisis), achieved permanency and changed Earth in its image. The general logic of this process suggests that fringe life on terrestrial planets must, at an early stage, make a transition from planetogenic to *astrogenic* life forms or perish.

In the Jovian environment, the anaerobic (except for photoautotrophic) and heterotrophic abyssal life floats in the food supplies produced by the planetary body at large, including those regions too hot for life to enter. The un-

NEW FRONTIERS

It is now almost 2 years since we opened this series probing into the far frontiers of Astronautics. In that time we have received many letters from readers in different parts of the world welcoming the approach. Our very first New Frontiers issue (*Spaceflight*, April 1970) stressed that one of the most compelling quests of the Future would be the search for evidence of intelligence elsewhere in the Galaxy. It is therefore gratifying to record that the First Soviet/U.S. Conference on Communications with Extraterrestrial Intelligence (CETI) — with British, Hungarian and Czechoslovakian participation — was held in Armenia last September. On pages 17-19 of this issue we give further details of this unique conference together with the recommendations which could lead to more comprehensive and co-ordinated searches of the nearer stars than those already made by Dr. F. D. Drake in the US and Dr. V. S. Troitsky in the Soviet Union. In addition we present — among other items related to interstellar communication — a major feature by Krafft A. Ehrlicke which attempts to assess stellar systems which may have evolved carbonaceous life.

Kenneth W. Gatland

changing, or only very slowly changing, placental bio-environment provides little incentive for life to evolve to higher forms that could lead eventually to the rise of intelligent creatures.

Therefore, it is reasonable to postulate that intelligent life is far more likely to emerge from fringe life on terrestrial planets — that is, in an astrogenic or star-dominated environment. This fact may offer us new clues in our search for alien intelligences and for intelligences that already might have achieved interstellar flight capability.

Since solar energy is the fundamental fuel of life and of the terrestrial biosphere (neither of which is the case in the Jovian environment), the entire complexion of all living matter, from diatom to Man, is thoroughly attuned to the

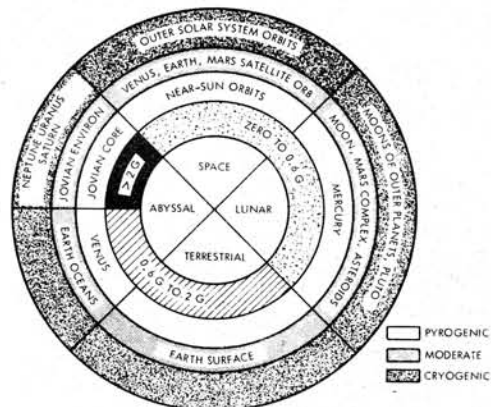


Fig. 1. Environmental Hierarchy.

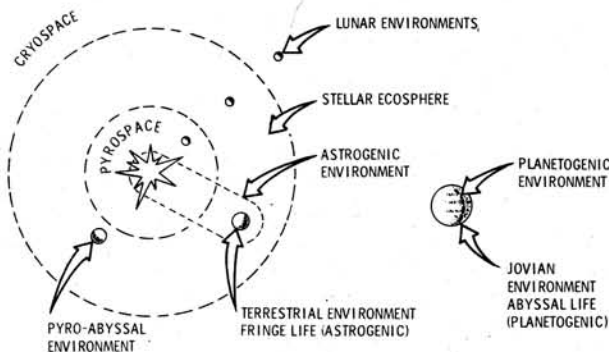


Fig. 2. Astrogenic and Planetogenic Environment.

radiation characteristics of our star. Our star also influenced or dominated the evolution and rate of evolution of terrestrial fringe life. Therefore, it is useful to broaden the conventional environmental concepts when applying our Sun-Earth experience to other starplanet systems (fig. 2).

Let the planet represent a given macro-environment which contains lower hierarchies of regional environments down to local and micro-environments. Temperature limitations for the development of carbonaceous life define a spherical shell around the star. H. Strughold [4] introduced the term *ecosphere* for this region in which the surface temperature of 'open' terrestrial planets with a relatively thin atmosphere lies within the appropriate limits. Therefore, terrestrial environments must be located in the star's *ecosphere*; lunar environments may be located inside or outside the *ecosphere*; and abyssal environments are most likely in or beyond, but not on the inside, of the *ecosphere*. Jovian environments, virtually by definition, can be expected to be located beyond the stellar *ecosphere*.

Since general reasoning, backed by the course of events at least in this Solar System, indicates that intelligent life has the greatest chance of emerging in a terrestrial environment, this environment alone is of concern in the subsequent discussion. The fact that this environment is astrogenic, is of great importance for our attempt to generalize the Sun-Earth experience to other stellar systems. While the *ecosphere* bounds the possible or at least plausible location of terrestrial environments, the concept of the astrogenic environment, as proposed here, encompasses the totality of star-life interactions which are largely unexplored.

Star-Life Interactions

A star can influence the evolution and the speed of evolution of life, if it affects those factors that drive the evolutionary process. If this correlation can be established, then it should be possible to establish a further connection between stellar type and the probability of intelligent life. Again, we have nothing more to go by than our terrestrial experience. But, the stream of terrestrial life is deep, wide and infinitely ramified and, therefore, may not be such an inadequate example at all. An initial discussion of the star-life correlation was presented in [5] and is subsequently expanded.

The genetic material of life forms is not completely invariant, but occasionally undergoes 'quantum jumps' of changes that remain constant over long time periods. The evolution of life to higher form and eventually to intelligences is based on a progression to more rational and efficient bio-structures of higher performance, increased intensity of living and greater autonomy *vis-a-vis* the environment. Thus, evolution requires change of direction toward higher quality. Change is provided by mutations; direction by natural selection. Thus the speed of evolution is a function not only of the mutative changes (which are without direction) but also of the speed with which natural selection 'filters' these changes to attain higher quality.

Astrogenic environments provide higher rates of mutation in the fringe life than the abyssal environments in the oceans of a terrestrial planet. For a given mutation rate, the rate of directional change is slower in a large population; but the breadth of change may be smaller in a smaller population. As to the first point, it is important to note that the formation of superior species in the oceans progressed more slowly than on land. Sea life was less subject to solar radiation effects and also less subject to environmental changes which are an important tool of natural selection. The result was a slow mutation rate, and a less pronounced and more uniform natural selection.

Moreover, sea life populations tend to be very large. In large populations it takes much longer before favourable recessive mutations (those that require that the mutation is present in both parents) become numerous enough to prevail. In small populations, new mutations constitute a comparatively high percentage of the population and can, therefore, gain prevalence more readily. On the other hand, if the population is small, then it is more likely that certain hereditary variations are lost accidentally. Therefore, small populations of a species tend to evolve faster but may have a relatively smaller breadth of variations than very large populations. The enormous variety of sea life and insect life, for example, contrasts strongly with the comparatively far smaller diversity of higher mammals and especially the primates and *homo sapiens*.

Mutations occur continuously. Mutation determines all characteristics of plant and animal species and must, therefore, be regarded as the primary motor of evolution. Mutations at the end of an evolutionary process (which is the case for practically all present terrestrial life forms) represent mostly disturbances of the individual's finely balanced and environmentally adapted genetic set-up; i.e., they have mostly derogatory or lethal effects, are sometimes indifferent, rarely favourable. But in the formative stages of life this was not the case. Life and planet had not yet grown into an integral unit and balance was not yet established, so that a far greater percentage of changes was then favourable. The higher the mutation rate, within limits, in life's formative stages, the faster could evolution progress to higher forms, given enough 'filters' of natural selection through which unfit mutations and gene combinations are eliminated. The only criterion for the enormous variety of anatomic forms possible through mutation is their biological viability. Therefore, in an environment that imposes relatively fewer innate (climatic) changes, such as the sea, the diversity can be enormous. Other drivers (hostile life forms and competition for preferred resources) powered the natural selection of oceanic life.

In a tougher environment, such as that of fringe life on

the Earth's surface, biological viability alone is not enough in the long run. Temporary or permanent changes in the innate environment (temperature maxima and minima, aridity, floodings, chemical changes especially of water and air), as well as hostile life forms, parasites, disease carriers, competition for resources (food, nesting places etc.) and mating competition molded fringe life more intensely.

Thus, higher mutation rate, intensified natural selection and relatively smaller population sizes of the species involved, all combined to greatly speed up the evolutionary tempo. Moreover, the selectivity in land life acted, as a result, in a different direction, namely toward higher information inputs and increased information handling capability. For mammals, the highest form of land life, the minimum time required for a new species to emerge is 10^5 to 10^6 years; for a new genus 10^6 to $3.5 \cdot 10^7$ years; for a new family 10^7 to $4.5 \cdot 10^7$ years; and for a new order $3.5 \cdot 10^7$ years to 10^8 years. Natural selection led, on Earth, to the evolutionary victory of the mammals over the reptiles. Moreover, in most phyla of the mammals, progress manifested itself by an increase in body size, successive increase in brain size and complexity, and by increase in the relative size of the forebrain.

A star can influence the evolutionary drivers in an astrogenic environment through radiation, temperature and possibly through the spectral intensity distribution. A 'tougher' environment stimulates bio-responses by encouraging mutations and eliminating unsuitable forms more quickly. Thus, a tougher environment tends to accelerate the evolutionary pace — up to a point. If environmental demands exceed the limits of biological flexibility and tolerance, life is destroyed, unless it has reached techno-scientific intelligence level with its vastly increased capability of manipulating conditions and processing innate matter. On Earth, the 'normal' production of mutants is presently about 0.1%. Increased temperatures increase the production of mutants as much as 5 times (to 0.5%). Hard radiation may increase the production still vastly more (to 50%). Then there is the correlation between temperature and metabolic process. Within limits, higher temperatures accelerate metabolic processes. This tends to reduce the life span and increase the flow of generations, hence the selective process.

Favourable mutations gain prevalence faster. If these conditions prevail during the early phases of life when mutations tend to have a comparatively more beneficial effect, the evolutionary process is almost certainly accelerated. This acceleration has a particularly profound effect on the overall time span between appearance of primordial viral and bacterial life and emergence of an intelligent species, because this early phase is most time-consuming. The fact that life, once it emerged from the oceans and became fringe life in an astrogenic environment, evolved faster due to an increased rate of mutation and more intense natural selection — facts which are the more remarkable if one considers the far greater complexity of the bio-structural tasks involved — suggests a strong effect of the star on the evolutionary process of fringe life in its domain. A star has less influence over abyssal life in terrestrial environments (such as the oceans of Earth). Therefore, if its influence in that domain is increased, evolution is likely to be accelerated in the early stages of life, thereby offering at least the possibility of more or less greatly reduced planetary gestation time to the birth of an intelligent species.

To gain greater influence in the upper (life-carrying) layers of primordial oceans of a terrestrial planet, the star must be hotter. Hotter stars emit more strongly in the blue light of the spectrum, causing greater amounts of the energy offered to be absorbed by the planet. There are of course many factors (reflectivity, atmospheric composition, speed of rotation, orientation of the axis of rotation, etc.) that may interfere with this process. But the basic trend should be toward higher energy levels of the environment (e.g. higher degree of atmospheric ionization, more intense cosmic radiation of stellar origin), even if the average temperatures are within tolerable limits for carbonaceous life (which, by definition, is the case in the stellar ecosphere). Warmer oceans alone raise the rate of mutation.

So far as the planetary macroclimate is concerned, higher incidence of radiation energy may also increase the frequency, and possibly the amplitude, of climatic variations — such as, for example, the flip-flop process of a warm age causing increased water evaporation, followed by increasing reflection of stellar energy by cloud covers, causing a cool-down, leading to an ice age in which the water is frozen out of the atmosphere, opening it again to the influx of stellar energy, whence the cycle starts anew. There are, of course, many complicating factors (land-water distribution, rotational speed and orientation of the axis, orbital shape etc.) to cloud this simplistic picture. But so long as we cannot study terrestrial planets about other stars — and until we have at least analyzed thoroughly the causal history of Venus, the only other terrestrial-sized planet in this Solar System, we can achieve only first approximations.

After the emergence of life from the water has been accelerated and the evolutionary stage of warm-blooded animals has been reached, the selective effectiveness of climatic variations is heightened further. Again taking the basic trends, in warm-blooded animals, a hot environment selectively leads to smaller forms; whereas ice ages favour the emergence of giant forms (mammoth, giant bear, deer, growing size of the horse and probably of Man as well, etc.) whose higher volume-to-surface ratio holds the internal body heat more favourably. Smaller forms lead to larger populations. This brings out a greater diversity of mutative variants from which the best are then selected as the population shrinks with an oncoming ice age. The best forms grow in size, including skull volume, enabling the brain to grow and increase in complexity and functional capability, driving the evolution of the senses due to the interdependence of information acquisition and information processing capabilities.

Thus, one might conclude that the planetary gestation period to the birth of an intelligent species is likely to be shortened, compared to the Earthian process, in such environment. Slightly higher mutation rates will be coupled with increased frequency and amplitude of innate environmental variations and associated oscillations in population sizes. Such astrogenic environment appears more plausible in association with stars that are hotter than our Sun. Conversely, in astrogenic environments controlled by cooler stars, the reverse seems to be true.

This conclusion does not mean that a rigid correlation can be established on the basis of the above, in the sense that life, if it exists on planets about hotter stars must necessarily be expected to develop faster, but only that drivers are present which, if allowed to be effective — and which have a fair probability of being effective due to the star's dominance of astrogenic environments — will reduce the gestation period

by perhaps as much as a thousand million years below the approximately 3,000 million long Earth period. Conversely, in cooler star environments, these drivers are significantly weakened, in which case the speed of evolution is slowed down.

Star and Civilization

The great mass of stars in the center of our galaxy consist of very old (Population II) stars, formed from clouds composed essentially of primordial hydrogen. Our Sun, and most of the stars in the spiral arms of our galaxy, are Population I stars, formed from gases which contained the (heavier) ejecta of the older Population II stars. Population I stars have metal-rich spectra. The heavier elements are more abundant by a factor of 100 - 200 than in Population II stars. Because of this, the dynamics of Population I proto-stellar clouds suggests a tendency to break up into smaller clouds; in other words they tend to form double stars and planetary systems. Observation shows that indeed the percentage of double stars is significantly higher among Population I stars than Population II stars. One can, therefore, expect that the occurrence of planetary systems, hence, of life, is more likely among Population I stars.

Very large Population I stars, those of spectral classes B0 through A5 (see Table 1), burn out fairly rapidly. In a matter of 10 million to 2,000 million years, they leave the main-sequence and become unstable. These stars seem to offer too little time for life to develop. From about F5 to K5, the period of stellar stability increases from 6,000 million to about 100,000 million years (fig. 3). It is among planets of these stars that life most likely has a chance to develop.

Stable existence of stars in the F-class of the spectrum ranges from 4,000 million to 6,000 million years. On Earth, life apparently began to develop 1.5 to 2 billion years after the Sun became a Main Sequence Star (about 4,500 million years ago). Intelligent life did not arise until about 3,000 million years after it had been stabilized on the basis of

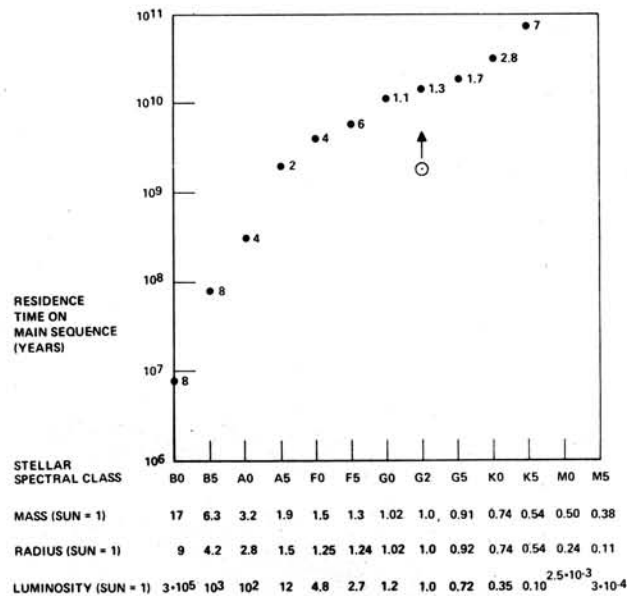


Fig. 3. Stellar Characteristics.

photosynthesis. If these time spans are somewhat characteristic in general — at least in the sense that they may be reducible only by 30% or less — then F-systems are at the critical threshold so far as time needed to develop intelligent life is concerned. An F-star civilisation could relatively soon face the prospect of its star swelling into a Giant. Consequently, civilisations would perish sooner or would be induced to develop interstellar flight operations with a comparatively greater urgency than civilisations in G-

Spectral Class	Description (Each class consists of 10 sub-classes: e.g. B0 to B9 etc.)	Star Temp (°K)	Typical Star Mass (Sun=1.0)	Typical Star Radius (Sun=1.0)	Approximate Stable Life Time (Years)	Rotation (km/sec)	Typical Luminosity (Sun=1.0)	Number of Stars in Solar Neighborhood (stars per 1000 pc ³ or per 30,000 cubic light years)
O	Very hot. Double ionized helium dominant	50,000	40	≥18	<8 Million	275-150	>300,000	0
B	Single ionized helium and hydrogen dominant and increasing B0 to B9	B0: 25,000 B5: 15,600	17 7	9 5	8 Million 80 Million	160 165	13,000 630	B0 to B9: 6
A	Hydrogen dominant. Double ionized calcium increasing A0 to A9	A0: 11,000 A5: 8,700	3.5 2.2	2.8 1.7	400 Million 2 Billion	150 125	80 20	A0 to A9: 9-10
F	Double ionized calcium dominant. Iron and other metals increasingly apparent in F0 to F9	F0: 7,600 F5: 6,600	1.8 1.4	1.3 1.25	4 Billion 6 Billion	75 20	6.3 2.5	F0 to F9: ~ 10
G	Double ionized calcium dominant. Iron and other metals abundant	G0: 6,000 G2: 5,800 (Sun) G5: 5,500	1.07 1.0 0.9	1.03 1.0 0.93	11 Billion 12 Billion 17 Billion	< 0	1.3 1.0 0.8	G0 to G9 ~ 11
K	Strong metal content. CH and CN appearing in K0 to K9	K0: 5,100 K5: 3,900	0.8 0.7	0.75 0.55	28 Billion 70 Billion	<10	0.4 0.16	K0 to K9: ~ 12
M	Very red stars. Titanium oxide (TiO) increasingly abundant in M0 to M9	M0: 3,600 M5: 3,000	0.5 0.4	0.25 0.11	100 Billion	<10	≤ 0.06 ≤ 0.001	M0 to M9: ~ 65

Table 1. Characteristics and Distribution of Main Sequence Stars by Spectral Classes in the Solar Neighbourhood.

or K-star systems. Star flight in F-civilisations would be a matter of survival of their species rather than of scientific curiosity alone.

The nearest F-star is Procyon (Alpha Canis Minor), spectral class F5, the brightest star in the Little Dipper, 11.3 ly away. There are very few F-stars in the solar neighbourhood, too few to render it statistically likely that a civilisation, readying itself for an interstellar exodus on the above grounds, exists in our vicinity.

The cool, reddish stars of the K- and M-class have extremely long periods of stable operation. Life and intelligences have virtually unlimited time to develop and to flourish. Planets which are as close to these stars as are Earth and Venus to our Sun experience temperatures comparable to those on Mars and asteroids. Life-bearing planets must gather more closely around a cool star. The region in which the star's radiation would support the evolution of life on planets like Earth or Mars, is considerably more compressed around K- and M-stars than around the larger and hotter G-stars – to which our Sun belongs – or even the F-stars. As the ecosphere moves closer to the star, its inner region begins to overlap with the region of arrested planetary rotation (cf. below). Assuming that life cannot arise on planets that always point one side to their star, this overlap reduces the extent of the 'useable' ecosphere. The astrogenic environment is less conducive to producing mutations. For example, the energy output of a 3000 K hot M-star (about 3000 kw sec/cm²) is only 5% of a G-star's like our Sun. Therefore, even though the radiation maximum is shifted to the more penetrating red wavelengths, the climate of planets in the useable ecosphere tends to be cooler and the temperature drop toward the poles still more pronounced than in the ecosphere of a G-star.

The thermal constraints above and below which carbonaceous life cannot develop, permit a temperature range roughly from $T_1 = 353^\circ\text{K}$ (80°C, 176°F) $T_2 = 203^\circ\text{K}$ (-70°C, -94°F). This defines a spherical shell (ecosphere) around a star of inner radius d_1 and outer radius d_2 . For a sufficiently rapidly rotating planet of roughly black-body characteristics (a condition that is rather closely met for planets with a carbon-nitrogen-oxygen atmosphere), the average temperature at the surface and in the lower atmosphere is given by $T = T^* R^*/2d$ where T^* is the surface temperature of the star, R^* the stellar radius and d the planet's distance from the star's centre. It is then possible to deduce the limits of the ecosphere, for the specified conditions, from

$$(1) \quad d_n = \frac{R^*}{2} \left(\frac{T^*}{T_n} \right)^2 \quad (n = 1, 2)$$

with T_1 determining the inner limit d_1 and T_2 the outer limit d_2 . At the ratio of the above temperatures $T_2/T_1 = 1.739$, the ratio of distances becomes $d_2/d_1 = 3.024$. This means that the absolute thickness of the ecosphere grows rapidly with the inner distance d_1 . When d_1 is small, the temperature zone is small also, reducing the probability that a planet of suitable size and mass is formed within its limits.

The above simple relations do not apply at close proximity where planetary rotation is restrained or synchronized with the period of revolution due to stellar gravitation effects. The intensity of stellar tidal forces per unit of planetary mass is a function of the stellar gravitational force $k^2 M^*/d_0^2$ (where k is the Gauss constant and d_0 the planet's distance

from the star of mass M^*), and of the planet's diameter divided by its orbital distance. Designating the radius of an imaginary planet *Hypotheticus* as r_{Hyp} , this ratio is $2 r_{\text{Hyp}}/d_0$. The tidal force is then determined by

$$(2) \quad \tau = 2 k^2 M^* r_{\text{Hyp}}/d_0^3$$

Planets whose radius is too small to hold an atmosphere at small distance produce a pyrolunar environment. In our solar system we have no sufficiently large planet with atmosphere close enough to the Sun to be in a condition of synchronous rotation. For a small, dense, rapidly hardening planet like Mercury, even a distance of 82 solar radii (0.387 AU) is apparently still outside the region of synchronous rotation. But for a larger planet this would probably not be the case. Our Moon, a large object relative to Earth, lies in the terrestrial zone of restrained rotation. In order to estimate the outer limits of this zone conservatively (i.e. not too close to the star), and outer limit in solar radii of 1.25 times the Earth-Moon distance in Earth radii – 75 solar radii, or 0.34 AU – is assumed for an Earth-size planet in the circumsolar zone of restrained rotation. Then, for *Hypotheticus* orbiting another star, the limiting distance of the zone of restrained rotation becomes ($M_\odot$ = solar mass),

$$(3) \quad d_\odot^* (\text{AU}) = 0.34 \left(\frac{M^*}{M_\odot} \right)^{1/3} \left(\frac{r_{\text{Hyp}}}{r_{\text{Ea}}} \right)^{1/3}$$

Considering that planets tend to be larger if formed at greater distance it seems reasonable to assume that the radius of *Hypotheticus* should be varied with the stellar spectral class, using $>1.5 r_{\text{Ea}}$ for hotter stars and $<1.5 r_{\text{Ea}}$ for the K- and M-classes. Using the nominal stellar masses as listed in fig. 3 for the range of stellar spectral classes, the dimensions of the ecosphere and the extent of the zone of synchronous rotation, the latter for the indicated radii of *Hypotheticus*, are shown in fig. 4. It is seen that the possibly biotic ecospheres are bounded by stellar lifetimes to the left and by the region of synchronous rotation on the right. The ecosphere itself defines the temperature

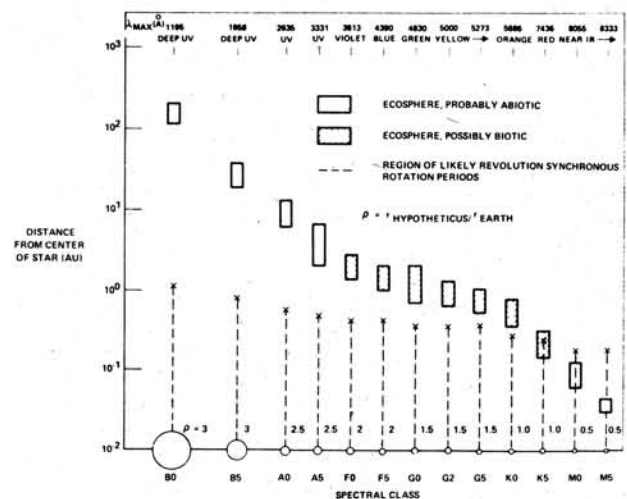


Fig. 4. Characteristics versus Stellar Spectral Class.

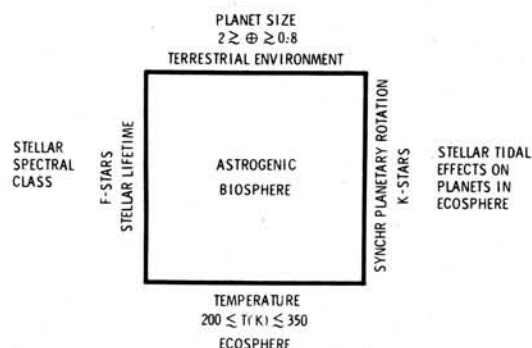


Fig. 5. Bounds for Existence of Astrogenic Biosphere.

bounds for stable, complex macro-molecules.

The size range of *Hypotheticus* represents the approximate bounds for the establishment of a terrestrial environment and an astrogenic biosphere. (fig. 5). Unfortunately, the necessity to use logarithmic scale at the ordinate of fig. 4 camouflages the enormous variation in the extent of the temperate region. For a nominal BO-star, for example, the inner limit (d_1) of the ecosphere lies at 105 AU, far beyond Pluto in our Solar System. The outer limit (d_2) lies at 319 AU. Therewith the ecosphere lies far beyond the limit of the restrained zone which, even for the assumed large planet size (3 Earth radii), extends only to 1.1 AU. At the other extreme, the ecosphere of a nominal M-5 star ranges from 0.016 to 0.03 AU and lies well inside the restrained zone that extends to 0.7 AU for a planet of approximately the size of Mars.

Thus, as one moves down the scale of spectral classes from G4 to KO to K5 and on, the stellar ecosphere overlaps increasingly with the sphere of restrained rotation. Life-bearing planets by and large will have a progressively colder climate. Life processes are slowed down. We may assume that it takes progressively longer for higher life forms and civilizations to develop. But the growing demand for time is met because of the increasing stable lifetime of those stars.

Thus, within the limit of basic feasibility of life development, the spectral class of the star might be used as a criterion which allows us to quantize, however tentatively, differences in evolutionary periods, rather than simply using the evolutionary periods of life on Earth as the only scale by which to judge the state of evolution of life — including intelligences — elsewhere. It would mean that around G5-, K- and perhaps even M-stars, there could be life forms and/or intelligences which are much older than anything comparable on Earth (provided their star is older) but not necessarily more advanced; or, if the star is of comparable age to our Sun, life may have existed there for about 3,000 million years, as on our planet, but may yet be far less advanced because it develops more slowly.

As one moves up the scale of spectral classes from G2- to GO and into the F-class of stars, the ecosphere becomes larger and moves farther away from the star, as stated before. Again, we have no 'proof' as yet that the 'contour' of our planetary

system (with an inner zone of small and an outer zone of giant planets) is representative. But, several factors would indicate that this is likely. One is that the gas dynamic conditions close to the star are not favourable for the formation or stability of massive secondary centres of gravity. The other is that among the invisible stellar companions confirmed or suspected — all 8 times or more Jupiter's mass — none is located at distances comparable to planetary distances in our inner Solar System, and most have orbital periods between those of Jupiter (11.86 yr) and Saturn (29.46 yr). If we use our Solar System as a model and shift the ecosphere outward, the small inner planets become too hot and larger planets in the central and outer regions of the planetary system become the potential carriers of life.

It must be remembered that if planets of the size of Jupiter or Saturn (assuming they have a rocky core, which at least Saturn is unlikely to possess) would circle a sun hot enough to place the ecosphere at their distance, they would appear much smaller, having lost their huge primordial atmosphere and replaced it by a lighter, more transparent one, although they would still be considerably more massive than a terrestrial planet in our system. Although surface gravities would be higher, they most likely are within 3 to 4 g. We have no reason to suspect that such g-levels would prohibit the evolution of life or of intelligences. In fact, if these intelligences undertake to conduct interstellar flight at those, to them comfortable, g-levels, they will easily become the greatest interstellar speeders. Thus, one might surmise that F-civilisations, and F-life in general — as we shall call the life forms around F-stars — were (or are) hatched in a relatively hot environment, on larger planets. If life originated basically in the same way as it originated on Earth — namely as the result of a multitude of chemical reactions in primeval atmosphere and oceans — the number of reactions per unit time on a large, warm planet of Uranus or Jupiter size must be very much greater than on Earth or smaller planets. Thus, it is not unreasonable to assume that life sprang up faster and evolved more rapidly in F-ecospheres. This would be a major factor in their chance to evolve an advanced technological civilisation fast enough to escape annihilation when their star begins to veer off the main sequence.

Another factor which could contribute to a more rapid advancement of their technological capabilities is the greater extent of their ecosphere, especially if it embraces several large planets. In that case, the probability of a plurality of inhabited planets on which civilisations arose independently is possibly significantly greater than in G-systems and almost certainly greater than in K-systems. This would obviously accelerate considerably the evolution of their interplanetary flight capability. It would also lead to social, philosophical and religious attitudes which conceivably are very different from ours, causing them to reach a state of space-minded enlightenment more rapidly and, in general, conditioning them psychologically for space and interstellar operations at a faster pace than we can apparently hope to condition ourselves. Even if independent civilisations did not arise on more than one planet, mere inhabitation of one or two other planets in their system would make a vast difference. One needs only to contemplate how in this Solar System the existence of another Earth would change our attitude toward interplanetary flight, especially if it were (unlikely) as yet unclaimed by an indigenous intelligence.

In between the 2 extremes, the F-systems and K-systems,

lie the G-type stars. They offer intermediate conditions in terms of stable stellar lifetime, size of their ecosphere and probably in terms of evolutionary pace. They are probably not more likely to have planets than K-stars, but they most likely have the highest probability that abundant life develops on at least one planet and that at least on the planet with the greatest abundance, intelligence will arise. These intelligences have sufficient time to develop into technological civilisations, judging by the stable lifetime of their star.

Thus, from the preceding discussion, a coarse pattern emerges of planets, life and civilisations whose first order commonalities are determined by the spectral type of their star. The correlation between stellar spectral class and stable lifetime of the star is reasonably well founded. Fringe life can possibly evolve only on terrestrial planets in an astrogenic environment within the star's ecosphere. Ecospheres around hot stars must be farther away and are more extensive than ecospheres around cooler stars.

The mass of main-sequence stars is known as a function of their spectral class with sufficient accuracy to determine the approximate extent of the region in which the star would significantly slow down or stop a planet's rotation within a period of 1,000 - 3,000 million years; and we can, therefore, deduce the approximate extent to which this region and the ecosphere overlap. Moreover, while we have no definite proof, there is nevertheless strong circumstantial evidence that planetary systems are at least a frequent occurrence among main-sequence stars from approximately spectral class F-2 on to K5. On the safe premise that chemical reactions are the same everywhere, carbon life is more flexible, more stable, more 'fit' to survive than life based on other chemical processes. This and the observed cosmic abundance of hydrogen, carbon, oxygen and nitrogen, all entitle one to the premise that the most likely — though not necessarily the only — forms of life are based on carbon and hydrogen as the principal elements.

If the size-distance relation of the planets in our system is somewhat typical, then the ecosphere of F-stars should, in general, contain larger planets, and that of K-stars smaller planets than the ecosphere of G-stars. The statistical probability that planets of F-stars may, in general, be larger than those of K-stars is somewhat enhanced by the fact that the mass of F-stars is larger (1.1 - 1.5 times), the mass of K-stars smaller (0.75 - 0.5 times), than that of typical G2 stars like our Sun. Because the extent of the ecosphere of F-stars is greater, the probability that F-systems contain more than one inhabitable planet should, in principle, be greater.

If life is more likely to arise on spinning — within certain spin rate limitations — than on planets with very slow rotation or no rotation at all, then the most likely life-bearing planets around K-stars are located in the outer region — on the cold end — of the ecosphere, because the available size of the ecosphere which is inherently smaller around the cool K-stars is reduced further by overlapping with the star's region of restrained or stopped planetary rotation. The probability that the available zone contains more than one inhabitable planet should be smaller than in the case of F-stars. Judging by the known evolutionary drivers of life on Earth and the astrogenic environment effects of stellar spectral classes (within the limits of F- to K-classes), life and intelligences could develop faster in F-systems, more slowly in K-systems, than in G-systems.

Thus, we are led to the very tentative conclusion that the pace of life and civilisations might be faster than ours in F-systems, where it must be faster in order to improve the survival chances of civilisations driven out of their Eden by an aging star much sooner than G- and K-type civilisations, and faced with the choice of finding refuge elsewhere in a near-stellar space or perishing without trace. This might be another example of the principle of compensation in nature, so consistently upheld in terrestrial life and in physical processes as well (principle of Le Chatelier). That is to say, for every threat a defense evolves and for every effect a compensating counter-effect arises. Here a defect in (stable star life) time could be compensated by trends toward faster development and greater activity. Again, this must be understood statistically. In many F-systems, time will simply be too short, or development of life too slow to reach a safe level before the star becomes a Giant. The point is that shorter stable life of the star — so long as it is at least in the low thousand million year range, say, no less than 3,000 to 4,000 million years — does not necessarily mean that life could not reach the level of a technological civilisation. At least we have no compelling reason to make this assumption, unless we postulate that the development pace of terrestrial life is the shortest possible anywhere.

Conversely, with evolution more likely to proceed slowly in the cooler environment of K-stars, their very long stable life compensates for the longer time needed.

F-Star Civilizations

Higher probability of urgency to reach interstellar flight capability could therefore result in F-civilizations being the first to achieve a significant level of interstellar expansion. The term urgency does, of course, not suggest urgency in the sense of everyday life or even in a limited historical sense. It refers to the significantly shorter stable life of F-stars and therefore to the fact that evolutionary processes must be faster from the beginning when only 4,000 million years instead of 10,000 or 70,000 million years are available. Specifically, the term refers to the need of reaching a stage of evolution where at least the beginnings of a technological civilisation are reached. Once this is accomplished, there is a burst of progress to the level of interstellar flight possibilities which is like a flash in terms of stellar evolution — a few centuries. But it could still take 10,000 or 100,000 of years, in terms of the origin's time, before a suitable abode is found and utilized.

Once interstellar flight capability exists, its application would most probably be continued. Expulsion from the original Eden would most likely be the trigger for continued interstellar search and expansion even after a new stellar home was found. But since these possible characteristics of F-civilisations are real — if, indeed, they exist at all — only statistically on a sampling base of, say, a spiral arm of our galaxy, such an event may not take place for millions of years within hundreds or thousands of light years of our Solar System. But even if it does, it is not necessarily we who would be visited. F-type stars are few and far between. The probability that they have planetary systems and contain planets desirable to aliens is lower than for G-stars. That could compound their problem and cause them to concentrate on these systems at the expense of — to them — less important G- and K-systems. This may simply be their brand of 'cost effectiveness'. It may not cost their relativistic ships much time to make a quick detour to a G2 star to look

for microbes or their descendants. But to Headquarters — the people back home who are, relativistically speaking, at rest — it may mean a loss of ship time by a few thousand years or more; and this they might not be willing to accept.

K-Star Civilizations

Conditions appear reversed in the case of K-civilizations.

Developing slowly in a highly stable environment, they might be in no hurry to develop interstellar flight capability, or might not even develop a desire for it. However, once they have reached the level of a technological civilisation, progress will be fast. It is conceivable that these civilisations might, in general, be more content than others to converse leisurely via radio and lasers with other civilisations. But eventually, at least the capability of traversing interstellar space will be there. What could be the incentives to embark on such missions? First, there are many K-stars around. These stars have a high probability of possessing planetary systems; and the majority of K-systems (at least around KO- to K5-stars) might contain at least one planet with life. Second, if the broad characteristics attributed to K-type civilisations apply, they should be accustomed to having time — very much of it. This, and the slowness of their pace in general, may enable them to operate in terms of long relevance constants. Their flights might more likely be in the nature of research and exploration missions and thus involve a high probability of visiting potentially interesting G-stars. But if these civilisations are developing more slowly, the probability of one having reached this advanced level in the vicinity of our Sun is again very small, because, again, we must distinguish between large-scale statistical trends and the local conditions in a region which contains only a diminutive sample of stars.

Advanced orbiting and lunar observatories will permit us to search systematically for planetary systems among the stars, at least out to about 7 parsec; and we may be able to actually observe systematic differences between stellar spectral classes so far as abundance of planetary systems is concerned, the structure of these systems and particularly of the planet population within the limits of stellar ecospheres. This is not only a scientific interest but also of significance in defining potentially worthwhile objects for attempts to make radio contact, as targets for unmanned probes and ultimately even for manned missions.

Stellar Ecospheres in the Sun's Vicinity

Ecospheres and zones of restrained rotation of stars 17 ly distance were computed by J. Gadosky [6]. Using his data for the ecospheres (converted to AU), but recomputing the zones of restrained rotation on the basis of the specifications presented earlier, the results for specific stars are presented in Table 2. The characteristic data of these individual stars deviate from the nominal values used for the spectral classes (Table 1). However, the general trend is obviously the same as that shown in fig. 4.

Within 7 parsecs (23 light years), there are about a hundred stars. The great majority, about 63, are M-stars; about 16 are K-stars; 6 are G-stars; and 4 are F-stars. There are no B-stars, but 4 A-stars. With a few exceptions, these stars move very slowly relative to the Sun which means that the group moves as a flock. It is reasonable to expect that most of them have travelled together since their formation and that they — and in fact stars in a much greater radius than 23 light years — condensed at about the same time, some 4,000 to 5,000 million years ago. One would then expect that the A- and F-stars are considerably more aged. Indeed, in both cases, 3 out of the 4 A- and F-stars are white dwarfs. There is only 1 F-star, *Procyon*, in the group — an F5-star whose stable life time should be about 6,000 million years.

To apply our previously presented statistical concepts to this single star would obviously have a low probability of being correct. If any of the other F-stars, which are now White Dwarfs, had a civilisation, it either perished or emigrated a very long time ago. They may have passed by or through our Solar System millions of years ago. Star ships of F-civilisations may have looked at *Procyon* a long time ago. *Procyon* is only 11.3 light years away. If its system is populated by a starfaring civilisation, they either chose to ignore us or to survey us without contact. The potential inhabitability of the *Procyon* system is discussed below. There are no other F-systems in our neighbourhood which might attract star ships from more distant F-civilisations to enter our 7-pc nearer vicinity; or even our greater environment as far as 100 - 200 pc away which is richer in K- than in F-stars.

Again, considering the constraints that small numbers impose upon the validity of statistical results, and considering further that there are only a few G-stars within 7-pc, it

Star	Spectr. Class	Dist. (LY)	Visual Brightness $L^*(O=1)$	Radius $R^*(O=1)$	Mass $M^*(O=1)$	Temp. $T^*(O=1)$	Distance of Ecosphere			Region of Arrested Synchronous Rotation	
							Inner d_1 (AU)	Outer d_2 (AU)	d_2-d_1 (AU)	d_0 (AU)	r_{Hyp}/r_{Ea}
Sirius A	A0	8.7	23	1.53	2.35	1.58	2.2	6.7	4.5	0.71	2.5
Procyon	F5	11.3	5.8	1.74	1.8	1.17	1.45	4.36	2.91	0.52	2
α Centauri	G2	4.3	1.0	0.99	1.25	0.9	0.5	1.5	1.0	0.43	1.5
Sun	G2	-	1.0	1.0	1.0	1.0	0.63	1.9	1.27	0.34	1.5
τ Ceti	sdG8	11.8	0.36	0.57	1.1	0.95	0.29	0.86	0.57	0.40	1.5
ϵ Eridani	K2	10.8	0.25	0.89	0.77	0.74	0.29	0.87	0.58	0.31	1.0
ϵ Indi	K5	11.4	0.12	1.01	0.65	0.69	0.30	0.89	0.59	0.29	1.0
Kapteyn = -45° 1841	sdM0	13.0	0.0012	0.24	0.52	0.56	0.046	0.13	0.084	0.22	0.5
BD = -12° 4523 = CC995	M4	13.4	0.0013	0.22	0.38	0.53	0.037	0.13	0.024	0.20	0.5

Table 2. Some Characteristic Dimensions of Ecospheres and Regions of Likely Synchronous Planetary Rotation Within 7 Parsecs Radius.

sd = subdwarf; r_{Ea} = radius of Earth; r_{Hyp} = radius of planet Hypotheticus

becomes likely that we are the only technological civilisation within this zone; but even if there are others, it is as probable that they are a few centuries or millenia behind us, as it is that they are ahead of us. There might be one or two K-systems with life, such as *Epsilon Eridani* (K2), but if evolution on these planets is 'typical' in the sense of the foregoing correlation between spectral class and rate of biological evolution, life there would be as yet on a lower evolutionary level than ours and not able to communicate with us.

J. Gadamsky, in his fore-mentioned paper, concludes that of the 55 stars within 17 ly radius (counting each star separately even in binary and trinary systems) only 16 possess ecospheres that are interesting from the standpoint of our limited present knowledge. Of these, only 5 are of primary interest (Group I); namely, in order of decreasing size of ecosphere, *Sirius A* (AO), *Altair* (A5), *Procyon* (F5), *α Centauri B* (K5) and Sun (G2). The mean ecospheric values for these stars are: inner limit, $d_1 = 1.385$ AU; outer limit, $d_2 = 4.15$ AU. The ecosphere is located well above the zone of restrained rotation whose mean extent is given as $d_0 = 0.59$ AU. The first 2 are unlikely candidates for reasons of life time. Group II comprises 11 stars, in this order of decreasing ecospheres: *α Centauri A* (G0), *70 Ophiuchi A* (K1), *σ^2 Eridani A* (K0), *ϵ Indi* (K5) *ϵ Eridani* (K2), *τ Ceti* (G4), *70 Ophiuchi B* (K5), *61 Cygni A* (K6), *Lacaille 8760* (M1), *61 Cygni B* (M0) and *CD = 37° 15492* (M3). Mean values for this group are (AU): $d_1 = 0.27$, $d_2 = 0.081$, $d_0 = 0.462$. These ecospheres are partially overlapped by the zone of synchronous rotation.

In Group I, only *Altair* and Sun are single stars, *α Centauri* is a triple star; *Sirius* and *Procyon* are binaries. Su-Shu Huang [7] and others have pointed out that the probability of planet formation in double and triple star system is reduced, compared to single stars, due to mutual gravitational perturbation. Planet formation should be feasible if either the distance between the components is quite large or if it is small. In the first case, the region of stable orbits around each component is so large that enough planetesimals could be retained for planetary accretion. In the second case, the components act as one central body and planets may be formed in more distant orbits outside the region in which the stars move about their barycentre. Thus, it is primarily in the case of multiples with intermediate distances from each other or multiples moving in more highly elliptic orbits, that the probability of planet formation is reduced significant-

ly. Table 3 lists a number of visual binaries. Their masses, closest distances and ecospheric zones are compared. The eccentricity of their orbits is very high.

Of the multiples shown in Table 3, *η Cassiopeiae* and *70 Ophiuchi* look comparatively most promising so far as the occurrence of ecospheric planets is concerned. *α Centauri* has a low probability of planet formation. The Primary has about twice the mass of the Secondary. There is also a tertiary (*Proxima*) which is more than half again as massive as the secondary. Primary and Secondary are a fairly large mean distance of 23.6 AU apart, but the Secondary's orbit is highly elliptic, causing the Secondary to approach fairly closely the Primary's ecosphere. The companion of *Sirius A* is a White Dwarf of approximately solar mass, circling the Primary at a mean distance of 20 AU, approaching the primary's ecosphere much too closely to expect stable planets in the ecosphere of *Sirius A*. The situation is also not favourable in the *Procyon* system where the Primary is accompanied by a White Dwarf of 0.65 solar mass, coming almost as close to the primary as Saturn is to the Sun.

Of the 11 stars in Group II only 5 are single, namely, *ϵ Indi*, *ϵ Eridani*, *τ Ceti*, *Lacaille 8760* and *CD = 37° 15492*. However, the binaries all involve very large distances between the components: 22.9 AU for *70 Ophiuchi*, 34 AU for *σ^2 Eridani B, C* and 82 AU for *61 Cygni*. In addition, with the exception of one component of *σ^2 Eridani*, all stars have smaller masses than the Sun. Finally, the spectral classes involved call for ecospheres close to the stars. On these grounds the ecospheres around each of the components are unaffected by the other component.

Many factors influence the probability that the ecospheres of the stars in both groups indeed contain life sustaining planets. These factors are quite numerous. They range from the more obvious requirements of appropriate planet size to such subtle factors as those involved in the as yet little understood causes for the great divergence in the evolution of Venus and Earth, 2 planets of almost identical size and mass, both located well in the Sun's ecosphere. If we would detect 2 planets like this in another Solar System, we would have to assume that both should be similar and that higher life evolved on both or on neither. Any notion that the 2 might be very different would necessarily have to be deduced from our knowledge of the difference between Venus and Earth rather than from generally valid analysis. If the life sustaining qualities of a planet are as sensitive a function of size and solar distance as the totally different

Table 3. Elements of Some Visual Binaries within 7 parsecs radius.

Star System	Distance (LY)	Component				Orbital Characteristics of Secondary About Primary Semi-Major Axis (AU)		Orbital Period of Syst. (Years)	Closest Dist. of Components (AU)	Location of Ecosphere (AU)
		Mass ($M_{\odot}$)		Spectral Class						
		A	B	A	B	Eccentricity				
α Centauri A, B	4.3	1.25	0.65	G0	K5	23.5	0.52	80.09	11.2	0.72-1.61
Sirius	8.7	2.35	0.98	A0	WD ¹⁾	19.2	0.59	49.94	7.9	2.25-6.75
61 Cygni	11.1	0.63	0.52	K6	M0	84.2	0.54 ²⁾	720	39	0.17-0.5
Procyon	11.3	1.8	0.46	F5	WD ¹⁾	16	0.32	40.6	10.9	1.45-4.36
70 Ophiuchi	16.4	0.9	0.65	K1	K5	22.9	0.50	87.6	11.4	0.42-1.27
η Cassiopeiae	19.2	0.94	0.58	G0	M0	70.5	0.43	400.9	40.2	0.67-2.0

1) WD = White Dwarf

2) Value estimated from general correlation between period and eccentricity in the orbits of binaries.

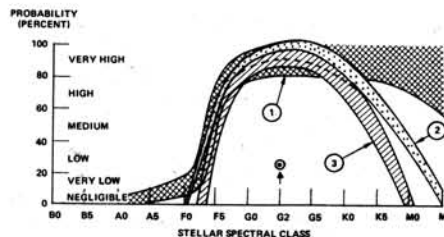
nature of these 2 planets would indicate, all present attempts to estimate the probability of alien life or intelligences in the Sun's neighbourhood are, at best, far more speculative than are the statistical estimates of the number of civilisations in the galaxy.

τ Ceti is a favourite candidate in searching for nearby stars likely to possess a life-sustaining planetary system [O. Stuve, S.-S. Huang]. Together with ϵ Eridani, τ Ceti was a primary target in Project Ozma, the search for intelligent radio signals conducted unsuccessfully in the early 60's by F. D. Drake and his team at the National Radio Astronomy Observatory [2]. B- and A-stars have high rotational velocity (c.f. Table 1). This is an indication that these stars have not shed much of their angular momentum. The number of planets (if any) might be small, but due to the greater width of the ecosphere some might nevertheless be found in that region.

Probability of Planets, Life and Intelligences as a Function of Stellar Class

The probability of the existence of planetary systems increases significantly beginning with the middle and late F-stars, whose rotational velocity is comparatively low and remains at a low level throughout the G, K and M classes. This trend is illustrated schematically in Fig. 6. Astronomers have long recognized that planet formation is an important means by which a single star during its formation (contraction of the proto-solar cloud) can shed excessive angular momentum that threatens to destroy its physical integrity. On this basis one may expect that single G-, K- and M-stars with masses comparable to that of the Sun (0.5 to 1.5) should have planetary systems. However, most of the middle and late M-stars within 7 parsec distance are small ($<0.5 M_{\odot}$). Greater abundance of metals and higher density suggest smaller dimension of the original proto-solar cloud, resulting in lesser rotational velocity build-up upon contraction. Thus for the middle and late M-classes the number of probability of planets may decrease again (curve (1)). This factor is compounded by a shrinking ecosphere and suggests that the probability of life-sustaining systems (curve (2)) diminishes rapidly beyond MO.

Curve (3) in fig. 6 shows the probability that intelligent life with manipulative capabilities has emerged or is developing, to be highest in the G- and early K-classes. This is not an ad hoc deduction, considering our G-civilisation, but is



- ① PROBABILITY THAT STAR HAS A PLANET SYSTEM
- ② PROBABILITY THAT ABUNDANT ASTROGENIC LIFE DEVELOPS AT LEAST ON ONE OF THE PLANETS ("GREEN PLANETS")
- ③ PROBABILITY ON AT LEAST ONE OF THE GREEN PLANETS, INTELLIGENT LIFE WITH MANIPULATIVE ABILITIES HAS DEVELOPED—AT LEAST TO HOMINID EQUIVALENCE

1. Probability that star has a planet system
2. Probability that abundant astrogenic life develops at least on one of the planets ("Green Planets")
3. Probability on at least one of the Green Planets, intelligent life with manipulative abilities has developed – at least to Hominid equivalence

Fig. 6. Probability of Planets, Life and Intelligences versus Spectral Class.

rather based on the fact that a combination of factors reduces the probability curve (3) to very low values at the hot and cold ends (FO and MO).

On the hot end, several factors come into play as we move down the F-class, from F9 to F0 and into the A-class. As the stars get hotter and their ecospheres move farther away, the average size of planets with a terrestrial environment increases. At first, as the planetary gestation period to birth of intelligent life decreases, the probability increases that terrestrial type planets with abundant life also harbour intelligences with manipulative capabilities. However, with increasing star temperatures, the ecosphere is being polluted to a growing extent with high-intensity stellar wind and with stellar flares. Maximum radiation intensity shifts toward the blue and ultraviolet highly ionizing radiation intensity increases. All of these factors continue to combine and to generate an increasingly 'hot' astrogenic environment,

Star	Dist. (LY)	Spectr. Class	Luminosity L^* ($\odot=1$)	T^* ($^{\circ}$ K)	Max. Light Intensity in	Mass M^* ($\odot=1$)	Radius R^* ($\odot=1$)	d_0 (AU)	d_1 (AU)	d_2 (AU)	d_2-d_1 (AU)
Altair	16.5	A5	8.3	9100	Near-UV	2.2	1.23	0.6	1.89	5.66	3.77
η Cassiopeiae A	19.2	G0	~ 1.6	6000	Yellow	0.94	1.1	0.35	0.67	2.0	1.33
Sun	-	G2	1.0	5700	Yellow	1.0	1.0	0.34	0.63	1.9	1.27
τ Ceti	11.8	G4	0.36	5400	Yellow	1.1	0.57	0.40	0.29	0.86	0.67
ϵ Eridani	10.8	K2	0.25	4200	Red	0.77	0.89	0.31	0.29	0.87	0.58
ϵ Indi	11.4	K5	0.12	3950	Red	0.65	1.01	0.29	0.30	0.89	0.59
70 Oph. A	16.4	K1	0.4	4800	Orange	0.81	1.04	0.32	0.42	1.27	0.85
α^2 Eridani A	16.3	K0	0.3	4400	Red	0.85	0.83	0.32	0.30	0.9	0.6

Table 4.
Characteristics of Stars within 7 parsecs radius where planets might exist and life be sustained.

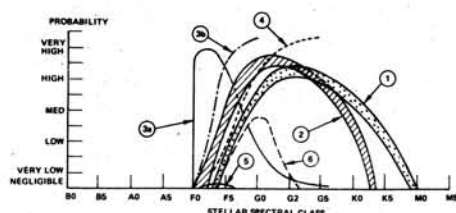
even in the ecosphere. This will eventually confine life to abyssal (oceanic, subterranean) enclaves on terrestrial type planets, because excessive mutation rates on land surfaces interfere with the evolution of fringe life. Therefore, one would expect the probability to decrease that planets with life also harbour intelligences.

In low F-subclasses, Main Sequence stellar lifetime becomes too short for higher life to develop. Stellar pollution of the ecosphere will increasingly interfere with the emergence of a terrestrial environment (open waters) in the first place by destroying the 'cold trap' in the atmosphere. This is an atmospheric layer sufficiently cold to freeze out water (and send it back toward the surface as precipitation) at an altitude at which stellar UV does not yet dissociate water to oxygen and hydrogen in sufficient quantities to cause a significant water 'leak' into space, depleting the planet of this vital substance before life even has a chance to arise. The availability of open water is the key to the emergence of a terrestrial environment on a suitably sized planet in the ecosphere. Thus, as the astrogenic environment becomes increasingly severe, it is likely, to first eliminate fringe life and eventually to prevent a terrestrial type environment, even on suitably sized planets in the stellar ecosphere. Finally, in the low F-subclasses and the A-class, the probability of planet formation decreases as evidenced by increasing stellar rotational speeds.

On the cold end of curves (3) and (2) other factors become important. The postulated slow-down in life's

evolutionary pace tends to lower the probability that on planets even with abundant life, intelligences have already arisen (remembering that stars at least within 7 parsecs are of roughly equal age). Shrinking ecospheres reduce the probability that they are occupied by a suitably sized planet. As the ecosphere becomes increasingly 'immersed' in the zone of increased rotation, the probability of life-carrying planets diminishes rapidly (curve (2)).

Probability curve (3) of fig. 6, multiplied by curves (1) and (2) of that figure, is shown qualitatively as probability curve (1) in fig. 7. The probability that advancement to a technological civilisation has been accomplished by now (curve (2)) shifts even more to the late F-stars, assuming reduced development time, and to the G-stars*, but drops sharply thereafter due to the postulated trend toward slower development. Curve (3a) indicates that any urgency to achieve interstellar flight capability, so far as a threat to the local environment is concerned, is dominant in F-civilisations; but (3b) indicates a lower probability that an emerging civilisation can be successful in developing that capability in time. An important reason for (3b) is that, at least in the early F-systems – given the emergence of life in the the first place – chances are higher that not enough time is available for life to reach a state of self-conscious brain development before the star threatens all life in its planetary system. The probability that another starfaring civilisation or even technological civilisation exists within a 7-pc radius from us is vanishingly small. The probability that manipulative intelligences exist somewhere between *Hominid* level and stone age should be higher. The probability that life-sustaining planets exist within 7 parsec is probably at least an order of magnitude higher than the previous probability. The probability of other planetary systems within 7 pc radius may be considered fairly high.



1. Probability that at least on one of the Green Planets, intelligent life with manipulative abilities has developed – at least to Hominid equivalence
2. Probability that intelligence on a Curve-1 Planet has – to this time – advanced to a technological civilisation comparable or superior to present Earth civilisation
- 3a. Probability of urgency to develop interstellar transport capability, imposed on emerging civilisation as a matter of extending its survivability
- 3b. Probability that emerging civilisation is successful in developing that capability
4. Probability of a 'Leisurely' evaluation of interstellar transport capability
5. Probability (3a) will occur within 7 parsec distance) Before we can have
6. Probability that (3b) will be successful within 7 parsec distance) achieved that capability

Fig. 7. Extra-solar civilisations and interstellar capabilities.

All illustrations, Space Division,
North American Rockwell Corporation.

Conclusions

Thus, we may once again find ourselves alone – that is, within the 7-parsec zone. We do not know whether our stellar neighbourhood is typical so far as the occurrence of intelligences is concerned. On the other hand, we are in a position to judge whether the stellar composition in our immediate neighbourhood is typical. Within 7 parsecs, the great majority of stars consists of M-stars; K-stars are second, followed by A-stars, G-stars and a distinct minority of F-stars. Many of the M-stars are flare stars (e.g. *Proxima Centauri*) and, therefore, unlikely to harbour astrogenic life. Within the Sun's wider neighbourhood of 20 pc, however, F-stars are almost as numerous as G-stars. M-stars are still the most popular class (75%), followed by K-stars (11%), G-stars (7%), F-stars (5%) and A-stars (2%) [8].

The number of qualifying F-stars is reduced by the fact that only the upper spectral sub-classes (F5 to F9) are, by virtue of their reduced rotational velocity, likely to have a significant planetary system and offer a sufficiently long stable lifetime to offer life a chance to develop. This leaves the G- and K-stars as the potentially most numerous group to harbour life. But, if the previously outlined assumptions regarding the influence of stellar spectral classes on the pace of biotic evolution in astrogenic environments are correct, the G-stars (lower subclasses G0 to G5) and the upper subclasses of the F-stars are the most likely to harbour advanced techno-scientific civilisations in the capability range from

*For stars of about the same age as our Sun.

interstellar communication to interstellar flight.

On this basis, our immediate (7 pc) stellar neighbourhood is not as likely to contain techno-scientific civilisations, as are other spheres of 7 pc radius elsewhere in the Sun's wider neighbourhood (approximately 20 pc), because of local paucity of qualifying F5 to F9 and G0 to G5 stars. The only single Main Sequence G-star in this spectral range is our Sun (G2). There is no single Main Sequence F-star in the Sun's immediate neighbourhood.

There is one other single G-star in the Sun's immediate neighbourhood, namely, B Hydri (G1, 21.3 ly). This is a Sub-Giant. Its main Sequence life terminated, a star swells to become first a Sub-Giant, then a Red Giant, probably in a time span of 10 to 20 million years. If B Hydri harbours a techno-scientific civilisation, it should be more advanced than ours and have ample cause to develop interstellar flight capability. Our Sun would be an attractive target star for their mission planning.

A third important G-star (a Centauri A, G2) is the Primary of a triple star system with a massive Secondary (A.Cent. B) in a highly eccentric orbit, approaching the ecosphere of the Primary too closely to render stable terrestrial planetary orbits, hence of stable astrogenic environments, likely, (apart from this) the presence of the massive Secondary argues against the emergence of a significant planetary system.

Procyon (F5) is also a Sub-Giant. Its companion is a White Dwarf, also in a significantly eccentric orbit. This means that the companion was most likely also an F-star, possibly an A-star. This system is unlikely to have produced a planetary system. But even if it had, the paroxysm of the dying nearby companion star must have wiped out a long time ago all chances for life to exist.

On the basis of this hypothesis, therefore, the immediate vicinity of our Sun offers a particularly low probability of finding a comparable or superior sister civilisation. But, contact with extrasolar intelligences (at least initial contact) is logically a matter of radio search, not of manned star flight. As such, distances are less critical and a sphere of wider radius can be searched, given the proper equipment. To us Earthians, the foremost significance of an interstellar flight capability lies in the evolution of the human species as a cosmic force. We must eventually reach other stars and

see for ourselves, even if we could be told by other star-faring intelligences. The immediate environment of our Sun offers a highly interesting variety of stars (3 different star types, including a flare star, already in the *Alpha Centauri* system) and a high probability of planetary systems, as is suggested by confirmed companions of Barnard's star (5.9 ly, M5) *Lalande* 21,185 (7.6 ly, M2), *61 Cygni* (11.2 ly, a binary (K5, K7) but with the Secondary far from the ecosphere of the Primary), and by the abundance of K- and M-stars. Some of their planets may well reflect to us the state of our terrestrial biosphere at an earlier stage and irrevocably lost details of the emergence of intelligent life on our planet.

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INTERSTELLAR BEACONS

By John W. Macvey.

Introduction

Continuing exploration of the Solar System during the coming decades must orient thinking more and more toward *interstellar* travel. Already the latter may be assuming the role once held by interplanetary travel — an enthralling future adventure but one still beyond the bounds of possibility. Such forward thinking is not a bad thing for it is right that protagonists of space travel should refuse to lean on past or present laurels. It seems fitting also that there always be room in astronautics for the visionary and romanticist. In planning how to cross the great gulf which separates star from star he (or she!) should find all the scope necessary.

That extra-solar planets exist at many points within our galaxy seems a reasonable premise today. In turn this invokes

the question of advanced and intelligent alien life-forms and civilisations. Here too there seems no valid reason for assuming this to be other than a distinct possibility. Since physical contact is rendered so appallingly difficult by the parameter of distance, communication by electronic means becomes increasingly attractive. This is not to suggest that there are no difficulties inherent in the concept. Radio waves, though they move with the speed of light, are still subject to considerable time lag (e.g. 3-4 years to the nearest star, 2½ million years to the nearest other galaxy). There must also be complexities in attempts to devise either a common language or a common mode of understanding. A further problem is where within our galaxy we can most likely anticipate the existence of alien societies.

So far interstellar communication has been considered largely in terms of electronics. In the circumstances this is hardly surprising since only radio would seem to offer the remotest hope of conveying intelligence between stars. Initially, however, signalling should be seen only as a means of announcing existence. When 2 reasonably close systems have indicated to each other that intelligent societies are domiciled in each centre, it will be time enough to consider the transmission of information.

Though radio appears to offer the best hope for data transmission, it may not be the ideal method of allowing advanced communities to announce their existence. Other techniques may prove of greater worth, and it is with such possibilities that this article is primarily concerned.

The Laser Beacon

In the light of present technology the use of laser beams is of distinct interest. Lasers represent a fairly recently acquired facet of our technology but one in which very considerable progress has already been made. We are in the habit of seeing interstellar communications as an exercise in the use of a particular portion of the electro-magnetic spectrum. The use of lasers parallels this by using a portion having much higher frequencies — that of visible light.

At first sight light seems to have much to commend it. Unfortunately ordinary light would be useless as a signalling medium over interstellar distances. Indeed it is doubtful whether it would serve between Earth and Mars. Only between Earth and Moon could it be regarded as a feasible proposition — and there a rather pointless one.

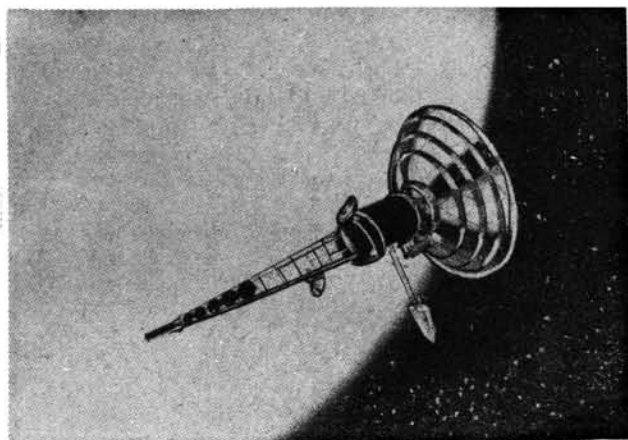
A beam of normally propagated light spreads out to a considerable degree and is thereby dissipated. As a consequence range is very severely restricted. If the individual rays comprising such a beam could be rendered parallel to those emanating from its centre, a tight, sharply defined beam would result. This is precisely what the laser achieves.

The word 'laser' is a term from the initial letters of the words 'Light Amplification by Stimulated Emission of Radiation'. It is a technique providing the purest and most intense light known. Indeed laser light is comparable to that emitted at the surface of the Sun.

Ordinary white light comprises light at many different wavelengths and these waves travel in all directions. It is therefore termed *incoherent* light. Light produced by a laser is for the most part of one wave-length only. Its waves are therefore unidirectional and have the effect of reinforcing one another. The resultant beam, narrow and sharply defined over long distances, is an example of *coherent* light.

Though the laser story began in 1958 it was not until 1961 that a device producing a steady beam (as opposed to pulses) was perfected. In May 1962 scientists at the Massachusetts Institute of Technology used the beam of a ruby laser to illuminate a 20 mile wide portion of the Moon's surface. The reflected beam was detected by ultra-sensitive measuring equipment on Earth. Had normal light been used this beam, due to spread, would have been equal to several times the diameter of the Moon (2,160 miles). It is therefore easy to appreciate the laser's potential as a 'light' communicator over great distances.

Two methods of using lasers in this manner have been suggested. The first envisages passing a laser beam through the optical system of a very large telescope. If the Hale reflector on Mount Palomar were used, the resultant beam would be 200 in. wide instead of the thin pencil-like beam



Space Observatory. Artist's impression of 'Project One', the Boeing Company's classic PARSECS study programme (Program for Astronomical Research and Scientific Experiments Concerning Space).

The Boeing Company

emitted by a laser alone. The other involves a cluster of perhaps 20 to 30 beams working in unison to produce a beam of coherent light 4 in. wide. In each case the effect of the atmosphere would be to scatter the beam to some extent. This disadvantage could be removed by placing the beam source *above* the atmosphere on an orbiting platform. This would obviously be more practical in the case of a laser cluster.

The use of a laser/giant telescope combination would, it is estimated, make possible a beam visible to the naked eye at a distance of 0.1 of a light year. Slight optical aid might render it visible to an observer 0.4 of a light year distant. A laser cluster on the other hand would give an appreciably poorer result — something of the order of 0.01 of a light year in the case of the unaided eye and 0.04 with slight optical aid. A 200 in. telescope at the receiving end would improve on this enormously. A beam would then be visible as far out as 10 light years and probably 2-3 light years in the case of a laser cluster.

There is unfortunately a complication. Let us suppose that a race on a planet of the star Sirius decided to indicate their existence to the Solar System by virtue of a super laser beam. To be habitable such a planet must not lie too far from its primary. Such distance in relation to that between Sirius and ourselves is trifling. Consequently laser light emanating from the Sirian planet would be obliterated by the vast outpouring of light from Sirius itself. Can this difficulty be overcome?

Each element absorbs light at a specific point in the spectrum. Because of this a series of black vertical lines are found along the visible spectrum of a star. Each such absorption line due to its position is characteristic of a particular element. If a laser on an extra-solar planet were to produce light of a wavelength such that a bright (emission) line were to appear in the centre of a black (absorption) band, an artificial characteristic would have been given to the spectrum of that star. In this way a laser beam might indicate its presence though itself lost in a flood of stellar light.

This seems an altogether too easy way round the problem and as might be suspected other difficulties remain. An artificial emission line within an absorption band might, because of its narrow width, remain imperceptible. So far as emission lines are concerned, brightness and breadth show inverse relationship; the brighter the line the more narrow and vice versa. Moreover position of the line within the absorption band would tend to wander due to axial rotation and orbital movement of the planet bearing the laser beam. This could only be rectified by continual appropriate alterations in laser frequency — no easy task.

The potential of the laser so far as interstellar communication is concerned is considerably less than that of the more orthodox radio. The superiority of the latter is particularly apparent in respect of range. Whereas radio signals could be transmitted over several hundred light years, their laser counterparts could at present barely exceed 10 light years. Background galactic interference is less at lower frequencies and this further favours radio. Visible light, of course, is merely electro-magnetic radiation of a much higher frequency. The construction of sufficiently large optical mirrors as 'receivers' also poses a problem whereas extremely large radio 'mirrors' (i.e. 'dish' reflectors) are already in existence.

These are difficulties which other civilisations within our galaxy may have resolved. If however the peoples of Earth are unable to overcome receiving problems in respect of lasers, no amount of expertise on the part of those transmitting coherent light signals is likely to avail.

It is conceivable that certain stellar communities have developed laser techniques before radio. To us the laser is new, its full potential as yet unrealised. Radio on the other hand has been with us to a greater or lesser degree since the closing years of the last century and consequently we tend to regard it as the simpler and more 'natural' concept. This in turn is conducive to the belief that, in every society, it must have preceded the laser. We might be entirely wrong in this belief.

An Interstellar 'Signature'

When discussing lasers we saw how the various elements in the atmosphere of the Sun and other stars absorb light at specific frequencies giving rise thereby to dark absorption lines. If an element not already present could be injected into a stellar atmosphere then an absorption line would appear which in normal circumstances would not be present. Such an occurrence might indicate to astronomers in neighbouring stellar systems the presence of intelligent life in the environs of the star concerned.

The main problem here is the availability of an appropriate element. So far the use of 'technetium' has been envisaged. This is a very rare element indeed; it was first produced in 1937 by Perrier and Segre at the University of California by bombarding molybdenum with deuterons or neutrons. It was later found that the element could be isolated in large amounts from the fission products of uranium. The obviously contrived name is due to the fact that technetium was the first element to be produced artificially. Production, however, was in extremely small amounts. Its presence has not so far manifested itself in the spectra of other solar type stars though it is believed to exist in stars of spectral group S.

For the purpose of the project relatively little of the element would in fact be necessary — some 2-300 tons. As the element is so rare, however, this represents a vast amount. Production would tax to the full the technological

resources of the most highly developed community and its successful injection into a stellar atmosphere would pose immense problems. To ensure the appearance of its characteristic absorption line would require a very uniform distribution throughout the atmosphere of the star concerned. Moreover, its presence would have to be maintained against the steady pressure of outflowing gas from the star.

It must be emphasised that this scheme, like that of 'laser' emission lines, can only be a form of marker beacon allowing an alien civilisation to 'announce' its existence.

The possibility of artificially blanketing the light from a star has also been raised. This envisages placing a dense cloud of particles in orbit around the star. By so doing its light would at set intervals be wholly or partially obscured. The mass of such a cloud would have to be very considerable (100,000 billion tons has been suggested!) and since it would comprise individual solid particles it would be prone to disruption.

Probably the most fantastic and certainly the most spectacular idea of all is one proposed by Dyson. This involves the total dismemberment of a planet, utilising the material to create a shell completely surrounding the parent star. This shell or envelope would be about 10 ft. thick and lie approximately 190 million miles from the stellar 'core'. The exterior of the shell would, it is believed, radiate to the same extent as the star itself but with one fundamental difference: the radiation would be confined entirely to the infra-red region of the spectrum. Such radiation could easily penetrate the atmosphere of a planet like our own. In the circumstances Dyson suggests searching for strong sources of radiation in the appropriate region of the infra-red band.

The complete disruption of a planet represents a task of such Herculean magnitude that it borders on the impossible. Nevertheless the Soviet astronomer Shklovsky has shown a willingness to endorse the general principles of the idea and has gone so far as to suggest that, since the Great Nebula in Andromeda can be surveyed in its entirety, it might be advantageous to look there since a marker beacon of such prominence should be detectable even at a distance of 2½ million light years.

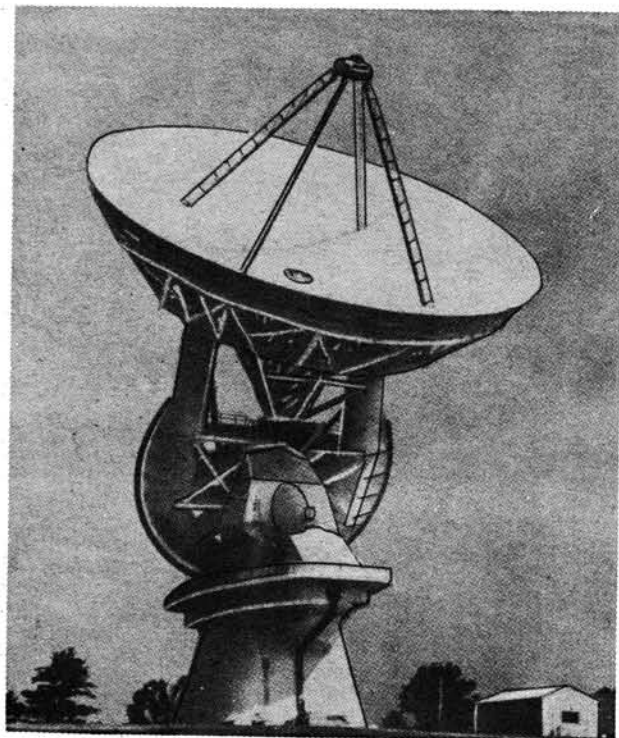
It has also been suggested that the presence of advanced cosmic races might be detected by the seemingly simple expedient of eavesdropping, i.e. listening for indigenous radio traffic. This does not imply domestic broadcasts though certainly if these could be picked up and understood they would be extremely revealing. What is envisaged is the interception of radio traffic between the individual planets of a system, communications between interplanetary space vessels, long-range radar pulses, etc.

Dr. Frank Drake, originator of the now almost legendary 'Project Ozma' believes that a listening programme along these lines might be practicable. Because such signals could so easily be missed or misconstrued, Drake proposes the use of extremely sensitive radio receivers in conjunction with radio telescopes, the latter being directed toward an appropriate and not too distant star. The procedure would be to examine the entire radio portion of the spectrum, probably in sections of 100 cycles at a time, recording the received noise. This achieved, the process would be repeated. If subsequently both tapes were played back in unison, any artificial signals would be superimposed and therefore strengthened. This would not be the case with random static.

[Continued on page 25]

SIGNALS FROM OTHER WORLDS*

By Boris Belitsky



Deep space radio telescope at the National Radio Astronomy Observatory near Green Bank, West Virginia. One of the largest equatorially-mounted instruments, it has a 42 metre dish reflector designed to amplify faint radio emissions from deepest space. It was at Green Bank in 1960 that a team under Dr. F. D. Drake, using a 26 metre diameter radio-telescope, began the search for extra-solar intelligence by focussing on the stars *Tau Ceti* and *Epsilon Eridani*.

United States Information Service

Communication with Extra-Terrestrial Intelligence, a problem now referred to in scientific jargon as CETI, was the subject of a recent conference at the Byurakan Astrophysical Observatory in Soviet Armenia (*Spaceflight*, Dec. 1971, pp. 464-5).

This was no conference of wild-eyed dreamers. It was convened by the Academy of Sciences of the Soviet Union and the National Academy of Sciences of the United States.

The host was one of the world's most eminent astronomers, Academician Viktor Ambartsumyan, the director of the Byurakan Observatory.

The scientists present included internationally recognised authorities in diverse fields, among them 2 Nobel Prize Laureates. One of the Laureates was Britain's Francis Crick, co-author of the celebrated double helix model of deoxyribonucleic acid (DNA).

The Soviet scientists included Academician Vitaly Ginzburg, the theoretical physicist and astrophysicist, and Prof. Iosif Shklovsky, a Corresponding Member of the Academy of Sciences specialising in radio-astronomy.

What was it that had brought all these distinguished scientists in different fields together at Byurakan? As Prof. Ambartsumyan said at the conference, 'The discovery of the very first extra-terrestrial civilisation could have colossal implications for man's destiny — it would be an event of the

same order of magnitude as the launching of Sputnik or the harnessing of atomic energy, if not more important.'

But is such a discovery really on the cards? The scientists at the conference differed on some aspects of the problem, but they were all agreed that the striking discoveries of recent years in astronomy, biology, computer science, and radiophysics have transferred the problem from the realm of speculation to the new realm of experiment and observation.

The conference considered the CETI problem in all its many aspects.

First, the astronomers Dr. Thomas Gold, director of the Centre for Radiophysics and Space Research at Cornell University, and Prof. V. Moroz of the Soviet Institute of Space Research initiated a discussion on the plurality of planetary systems in the Universe.

The astronomical evidence cited in this discussion supported the view that our Solar System is no exception in the Universe. Indeed, planetary systems appear to be very widespread.

From there the conference went on to consider the likelihood of life arising on other worlds in the Universe. Here the main contributions to the discussion came from the exobiologists. This term too is a relative newcomer to scientific jargon and refers to scientists concerned with extra-terrestrial biology.

In the view of Prof. Carl Sagan, one of the most versatile and enthusiastic exobiologists in the US, the idea that life on Earth is not unique is one of the most fruitful in modern science.

But even assuming life elsewhere in the Universe to be widespread, how likely is that life to have evolved to the stage of intelligence? This proved to be one of the most controversial points discussed by the conference.

Nevertheless, all the scientists present agreed that the likelihood of extra-terrestrial civilisations existing is sufficiently high to justify initiating a variety of search programmes.

Some preliminary radio-astronomical searches of this kind have now been conducted in the US and in the Soviet Union.

In the US this took the form of Project Ozma, whereby the big radio telescope of the National Radio Astronomy Observatory at Green Bank, West Virginia, was aimed at 2 nearby stars to see if, by any chance, there might not be intelligent signals emanating from them.

Dr. Frank Drake, who directed this project, was one of the most active participants in the Byurakan conference. He is convinced the failure to detect intelligent signals under this initial experiment cannot in anyway serve as an argument against further search programmes.

A more elaborate programme of observations than Project Ozma was reported at the conference by the prominent Soviet radio-astronomer Dr. Vsevolod Troitsky of the Radiophysical Institute in Gorky.

He told the conference of his observations of stars 100 light years away by means of specially designed apparatus operating in the centimetre and decimetre wavebands.

Troitsky's further work will undoubtedly be followed with the greatest attention by everyone interested in the CETI problem.

There were also many other highly interesting contributions to the discussion. Dr. Nikolai Kardashov, a brilliant

* Supplied by Novosti Press Agency

young radio-astronomer, examined the astrophysical aspect of the problem of searching for intelligent life in the Universe. Academician Vitaly Ginzburg presented a strong case in support of the validity of physical laws as we know them in other parts of the Universe, as yet unexplored. Dr. Lev Gindilis, one of the keenest of the Soviet enthusiasts in this field, discussed the possibilities of radio contact with other civilisations and Dr. Charles Townes, the Nobel Prize Winner, drew attention to the possible usefulness of laser techniques in CETI.

What all the scientists present agreed upon was that the problem of CETI is of profound significance for the future of mankind. Should extra-terrestrial civilisations be discovered, the effect on human scientific and technological capabilities would be immense.

They agreed too that the problem is one that requires a large measure of international scientific co-operation. As Shklovsky remarked privately before the conference, 'Before we really tackle the problem of communicating with extra-terrestrial intelligences, it would be a good thing to achieve communication on the subject between different countries'.

Coming as it did from one of the boldest and most imaginative radio-astronomers of our day, this remark reflected a view as far-sighted as it was sound.

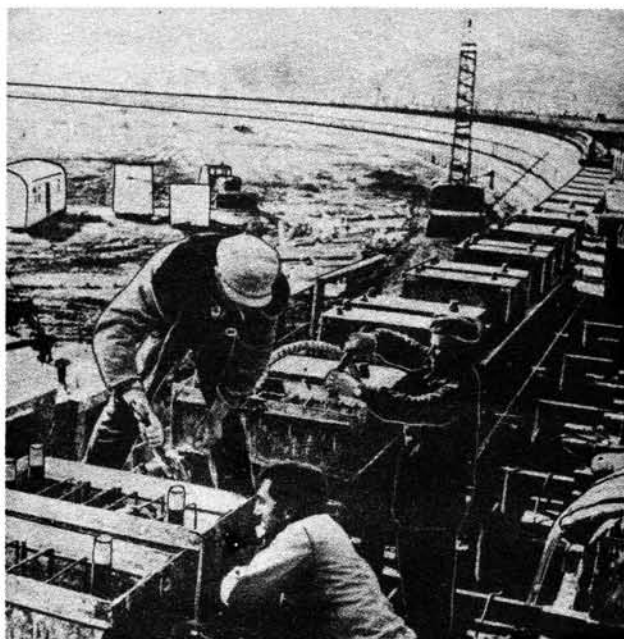
FIRST SOVIET-AMERICAN CONFERENCE ON COMMUNICATION WITH EXTRA-TERRESTRIAL INTELLIGENCE (CETI)

Resolutions

The first international conference on the problem of extra-terrestrial civilisations, and contact with them, was held between 5-11 Sept. 1971 at the Byurakan Astrophysical Observatory of the Armenian Academy of Sciences, USSR. The Conference was a gathering of qualified scientists working in a variety of fields — astronomy, physics, radiophysics, computer science and technology, chemistry, biology, linguistics, archaeology, anthropology, sociology, and history. The conference was jointly organised by the U.S. National Academy of Sciences (with assistance from the U.S. National Science Foundation) and the U.S.S.R. Academy of Sciences. Scientists from several other nations participated.

Many aspects of the problem of extra-terrestrial civilisations were discussed in detail in the 10 sessions of the Conference. Particular attention was devoted to the following questions: the plurality of planetary systems in the Universe, the origin of life on Earth, the possibility of life arising on cosmic bodies, the origin and evolution of intelligence, the origin and development of technological civilisations, problems in searching for intelligent signals or for evidence of astroengineering activities, and the problems and possible consequences of establishing contact with extra-terrestrial civilisations.

Conference participants differed on many details of these questions, but were agreed that the promise of contact with such extra-terrestrial civilisations is sufficiently high to justify initiating a variety of well-formulated search programmes; they also agreed that present technology may be capable of establishing contact with such civilisations. Some preliminary radioastronomical searches have been performed both in the US and in the USSR.



The Rata-600 radio telescope with a 600 metre antenna being built by Soviet engineers in the Northern Caucasus. Photograph shows supports for the Rata-600 as they appeared in November 1970. The huge instrument is designed 'to catch faint signals from distant stars and nebulae and to maintain long-range space communications'.

Novosti Press Agency

The conference participants reached the following conclusions:

1. The striking discoveries of recent years in the fields of astronomy, biology, computer science and radiophysics have transferred some of the problems of extra-terrestrial civilisations and their detection from the realm of speculation to a new realm of experiment and observation. For the first time in human history it has become possible to make serious and detailed experimental investigations of this fundamental and important problem.
2. This problem may prove to be of profound significance for the future development of Mankind. If extra-terrestrial civilisations are ever discovered the affect on human scientific and technological capabilities will be immense, and the discovery can positively influence the whole future of Man. The practical and philosophical significance of a successful contact with an extra-terrestrial civilisation would be so enormous as to justify the expenditure of substantial efforts. The consequence of such a discovery would greatly add to the total of human knowledge.
3. The technological and scientific resources of our planet are already large enough to permit us to begin investigations direct towards the search for extra-terrestrial intelligence. As a rule, such studies should provide important scientific results even when specific searches for extra-terrestrial intelligence do not succeed. At present these investigations can be carried out effectively in the various countries by their own scientific institutions. Even at this early stage, however, it would be useful to discuss and co-ordinate specific programmes of research and to exchange scientific information. In the future it

first day's runs by A and B (which correspond to both sequential and time matching) since they were already in JBR's checkup and it was desired to maintain the statistical independence of the checks. We therefore checked the guess-runs against the target runs with the closest time correspondence. In those cases where the closest times fell on different calendar days we also checked guesses against targets for the same calendar day since we were unaware of the subject's ideas in these cases. In total there were 12 runs checked with all 4 subjects included in the analysis.

There were 9 guess-runs checked against the nearest corresponding time and 3 additional checks to resolve the calendar day uncertainty. In most cases the time difference between target time and guess times were less than 2 hours but in some cases were up to 13 hours, for this analysis. These 12 runs gave a strikingly low score of 35 hits, with 60 expected from chance. This is so far below chance (-25) that the odds are approximately 3000 to one against it being a chance result. The odds are much greater still if we take only the 7 runs which can be matched to targets on the same calendar day.

Were ESP results valid?

The first point to be made of these independently checked results is that they are not chance; and if not they indicate extrasensory exchange. In fact they indicate a well known principle of ESP, or more broadly, of psi ('psychic') ability — namely, that it sometimes shows up in 2 directions, positive and negative. It can just as well be used to miss a target as well as to hit it. And since it works unconsciously, subjects A and B were not aware that they were hitting above chance on the target-runs-in-sequence (JBR plan) and avoiding (even more successfully) those on the rather hazardous time coincidence (EDM Plan).

In New York, Dr. Osiris conducted an entirely independent analysis which supports the results reported here. In the full report there are supporting analyses that bring out the rationale of this interpretation and indicate more of the way ESP was working as the subjects groped, utilizing a poorly understood energy concept, for contact with targets located somewhere in a space-time continuum. Certain minor details remain to be refined, and a number of questions must be given further attention before the total analysis is complete.

For example, it was not my intention to test the effect of distance on ESP in any crucial way; rather, this was just an opportunity to explore the questions in the unique situation the flight afforded and to see what would happen. At any rate no comment is presently in order on this point except that it looks as though, as many others have concluded, neither space nor time seem to limit, in an easily identified way, the function tested here.

Was it telepathy or another type of ESP? The present consensus in parapsychology is that there is really only one basic 'psychic' or psi ability of which the several types are manifestations.

From the experiment some unanticipated findings have already emerged that would seem to have promise and the old results as well as new plans will be under study. In my judgement the experiment warrants continued enquiry which I shall hope to pursue as opportunity permits.

I would like to express my appreciation to Dr. Rhine, Dr. Osiris and their respective staffs for the immense help they have provided. I also want to express thanks to NASA and my professional colleagues for their cooperation, without which this report could not have been made. Finally, my thanks to all those who have shown interest and given encouragement during the analysis and preparation of the report.

SOME LIMITATIONS OF THE INTERSTELLAR RAMJET

By Anthony R. Martin.

1. Introduction

Recently Alan Bond [1] surveyed the prospects of various propulsion systems which have been envisaged for carrying man to the stars and enabling him to make direct contact with other worlds and, hopefully, other civilisations. In his paper Bond placed the concept of the interstellar ramjet (ISR) in the position of greatest potential, and indeed its theoretical capabilities are enormous.

The difficulties associated with high speed (relativistic) travel in an interstellar vehicle which carries its own fuel are too well known to be detailed here [2-4]. Briefly, if the most energetic thermonuclear reactions are considered, then it can be shown that the vehicle is capable of reaching $0.1c$ (where c = velocity of light = 3×10^8 m/sec.), and that the maximum attainable acceleration is about $0.001g_0$ (where g_0 = acceleration due to gravity on the Earth = 9.81 m/sec²). These 2 limitations lead to flight times of hundreds of years to even the nearest stars. If the total conversion of matter to radiative energy is considered (and radiation loss is assumed to be zero) then accelerations of $1g_0$ can be

achieved, but require impossibly high mass ratios of the order of 10^9 , leading to enormous initial vehicle masses and fuel loads.

These problems caused Robert Bussard to study the concept of a ramjet-like vehicle which uses the interstellar medium as a fuel [5], and this is the concept with which this paper is concerned. Although the problems involved in designing a practical ramjet system are considered in detail, and most of the conclusions drawn are adverse ones, this is not meant to disprove the validity of the concept, but to point out some physical and technical difficulties which must be overcome.

Advances in technology will be made in the future which no-one can predict with any certainty today, and the capabilities of our civilisation in even a few decades time will surely be far beyond the level of the present (always assuming that international relations and regard for our fellow man also improve greatly in the future). In addition, the ISR concept is the only one suggested so far which is

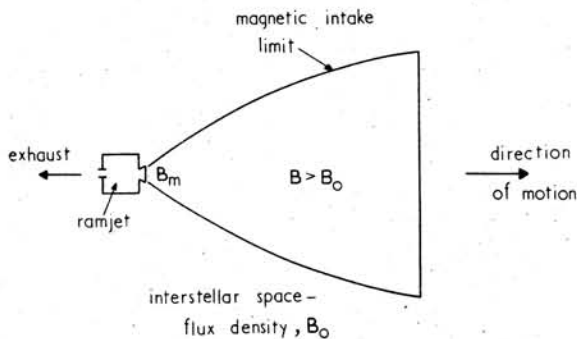


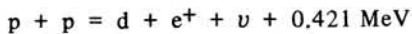
Fig. 1. Ramjet magnetic intake configuration schematic.

capable of giving man the means for true interstellar flight, and as such it is worthy of detailed study.

2. The Interstellar Ramjet

In concept the ISR is very simple. Interstellar space is filled with hydrogen gas in varying quantities, some in the neutral and some in the ionised form. This gas is collected by an intake on the interstellar vehicle and is fed into a thermonuclear reactor which converts a certain amount of the mass into energy in a fusion reaction. This energy is then used to accelerate the unconverted matter out of the rear of the vehicle to provide a thrust force. Further details of the concept can be found in Bussard's original paper [5], and in the paper by Carl Sagan [6] who gives a favourable appraisal of the system.

The fusion reaction is assumed to use one of the 2 main isotopes of hydrogen, i.e. protons or deuterium. The proton chain can be represented as



where p represents a proton, d a deuteron and e^+ a positron. The deuteron chain has a reaction cross-section over 20 orders of magnitude larger than the proton fusion reaction, but the energy yield is smaller and there is only about one deuteron for every 8,000 protons in interstellar space.

The particle intake on the vehicle is responsible for most of the problems which arise when the ISR is studied in detail. Bussard showed that the ratio of the frontal area loading density of the ramjet to the charged particle number density must have a value at least as large as 10^{-13} (kgm/m²) per unit reactive nucleon number density to attain an acceleration of $1g_0$. This implies that, for a vehicle mass of 10^6 kgm (about 1,000 British tons), operation in a region of high hydrogen density (10^9 particles/m³) requires an intake radius of about 60 km, and operation in a low density region (10^6 particles/m³) needs a radius of 2,000 km. These densities are the approximate limits of hydrogen ion clouds in interstellar space.

Such large sizes effectively rule out the use of solid materials, as the structural densities would be far too large. In addition, the surfaces of such intakes would be continually heated and eroded by the bombardment of high energy

particles which are being collected, and would rapidly fracture and lose their structural integrity.

Therefore the intake is usually considered to be a magnetic type, in which hydrogen ions are collected by the magnetic field lines and fed into the reactor mouth at the front of the vehicle. If the hydrogen in space is not ionised this can be easily accomplished by shining a light beam ahead of the ISR, thus causing photoionisation to occur. A schematic picture of such an intake is shown in Fig. 1 (not to scale). The spatial limit of the intake is given when the magnetic flux density, B , is equal to that of the interstellar magnetic field ($B_0 = 10^{-10}$ tesla). Inside the intake B is greater than B_0 , and rises to a maximum value of B_m near the mouth of the reactor.

However, the use of such an intake, as noted above, gives rise to several problems in technology. This is the subject of the remainder of this paper.

3. Energy Loss from the Interstellar Fuel

The equations of ramjet efficiency and motion derived by Bussard did not allow for the loss mechanisms which will be present in any practical ISR. The cases where the original relative kinetic energy of the interstellar gas is used with a loss of mass and radiation have been studied by Marx [7], and the case for a mass loss has also been treated by Opik [8].

Considering the mass loss case first, suppose that a fraction k of the interstellar gas is lost during the operation of the fuel utilisation cycle and that a mass fraction ϵ is lost by fission i.e. converted into energy in the reactor. If a mass dm of material is absorbed, a fraction ϵdmc^2 is changed into useful kinetic energy. If the propellant is protons then $\epsilon = 0.0071$, and if it is deuterium then $\epsilon = 0.001$. The exhausted mass fraction (which produces the thrust) is equal to $(1-\epsilon-k)dm$, and a fraction kdm is lost into space, has no velocity in the vehicle co-ordinate system, and is useless.

Marx solved the energy and momentum balance equations of the ISR for the case of this mass loss. Defining a variable $\gamma = (1 - v^2/c^2)^{-1/2}$ i.e. the usual relativistic factor, then it can be shown that if $(\gamma - 1) \ll \epsilon/k$ the mass loss has very little effect upon the motion of the ISR (i.e. it is unimportant at low velocities). However, as $(\gamma - 1)$ approaches the value of ϵ/k it can do so only asymptotically. That is, if the energy gain ϵdmc^2 equals the energy loss $k dmc^2 (\gamma - 1)$ then further acceleration will be impossible. For a realistic design k will never be zero, and so the vehicle cannot approach the velocity of light as closely as one would like. For acceleration to continue there must be a maximum value of k , given by $k_{\max} = \epsilon / (\gamma - 1)$, and this value is shown as a function of velocity for the proton chain in Fig. 2. It can be seen that $k_{\max}$ decreases as the velocity increases i.e. the limitation becomes more restrictive.

Opik [8] arrived at essentially the same result, but noted that the efficiency of the fusion reaction will not be unity, as assumed above, but nearer a value of 0.6 owing to the energy loss, due to gamma particles and neutrinos, from the system.

The case where radiation is lost from the intake was treated in a similar manner by Marx. As the fuel reaches very high temperatures in the fusion reactor and as the charged particles are very energetic at the mouth of the reactor some of the energy will be lost in the form of radiation. This loss fraction, λ , will be isotropic in the

vehicle co-ordinate system and it will carry no momentum. Here the limiting value of the loss fraction, above which acceleration ceases to be possible, is given by $\lambda_{\max} = \epsilon/(\gamma-1)^2$ and this value is also shown in Fig. 2.

It can be seen that the radiation losses dominate the problem for v/c greater than 0.9, and that very small values of the loss fraction must be present in the system. This limitation is an essential consequence of the ISR principle, and the only method of reaching higher velocities is to reduce the losses from the intake by some means. The origins of such losses are the subject of the next section.

4. Plasma Containment Problems

In any reasonable interstellar region the thermal motion of the gas particles can be neglected, i.e. the gas will be travelling backwards at the same velocity as the ISR is moving forward (in the vehicle co-ordinate frame). This means that, especially at higher velocities, the problems of containment of the plasma fuel (ionised gases) by the magnetic intake will be serious ones.

The magnetic field must not possess any large discontinuities which will allow the fuel mass to escape past the vehicle, or which will trap it ahead of the reactor inlet, where it will gradually radiate energy. This leads to the condition that the field must be slowly varying, so that the field that the particles see does not change significantly over one period of gyration of their motion. The general stability of such fields is questionable, and the fact that the initial gyration radii of the particles, in the weak fields at the limits of the intake, are so large (about 100 km) poses another difficulty.

The problem of plasma containment by magnetic fields is a familiar one in the area of controlled thermonuclear fusion research, and is responsible for many of the difficulties which have prevented the construction of a working reactor. As the magnetic field strength is increased a large number of instabilities develop [9], all of which would destroy the particle trapping properties of an intake, causing it to fracture and leading to a large fuel mass loss. Many different (and complex) field configurations have been tried, but have not met with complete success as yet. Even if the problem is solved in the case of a fusion reactor the scale involved in the ISR is many times larger, and small

instabilities which can perhaps be tolerated in a reactor will assume destructive proportions in the intake.

However, the containment of the plasma raises another problem. As the ions and electrons spiral about the magnetic field lines on their passage towards the reactor mouth the centripetal acceleration of the charged gyrating particles is accompanied by the emission of radiation. This is the so-called synchrotron (or cyclotron) radiation [9], and is a function of the squares of the particle number density and temperature. Now both of these quantities rise as the particles move towards the reactor and so the radiation emission increases. Therefore, the problem reverts to that of the previous section, where it was seen that very small radiation loss factors must be present in order for the acceleration to continue.

5. Structural Limitations

The initial theory of the ISR as developed by Bussard has been extended by Fishback [10] who investigated a more detailed model of the magnetic intake, and in particular limitations placed upon the motion of the ISR by the structure of the vehicle.

Fishback assumed the requirement that the section of the vehicle which contains the sources of the magnetic fields must be strong enough to withstand the forces exerted upon these sources by the fields which they create. That is, it is assumed that the magnetic field energy must be balanced by mechanical forces. Fishback equated expressions for these magnetic and mechanical forces and derived an expression for the minimum mass of the structure which is needed to support the field. (The first detailed investigation of the fact that such a minimum mass is needed was carried out by Kash [11]).

Known materials are limited in the values of their maximum tensile strengths, i.e. the amount of force that they can withstand before breaking up. Now, as will be seen in detail in the next section, the magnetic flux density of the intake increases, in order to be able to confine the charged particles, as the velocity of the ISR increases; and so the energy which must be contained by the structure also increases.

Therefore there must come a point where the acceleration of the vehicle must be reduced to avoid the breakdown of the vehicle structure by the magnetic forces. Fishback derived an expression for this cut-off velocity (for the most optimistic interpretation of the minimum mass theorem) and showed that the cut-off was proportional to the ratio of the maximum tensile strength to the density of the material used. Acceleration is still possible beyond this cut-off but the level must be reduced to compensate for the added strain produced by the magnetic field with the increasing velocity.

Fishback's numerical results are in error by an order of magnitude, and so the situation is not as restrictive as his figures suggest. In the case of travel in a low density region (see Section 2) the deuterium chain has no applicability due to the low number density and the low value of the energy conversion fraction. Table 1 shows the corrected results for the proton chain for some of the materials considered by Fishback. The values of the ship elapsed time, t_s , before the ISR must decrease its acceleration and the distances, S , travelled during this time, are given for the case of an initial $1g_0$ acceleration. These values were calculated using relativistic rocket equations (see e.g. [6]) for a flight profile

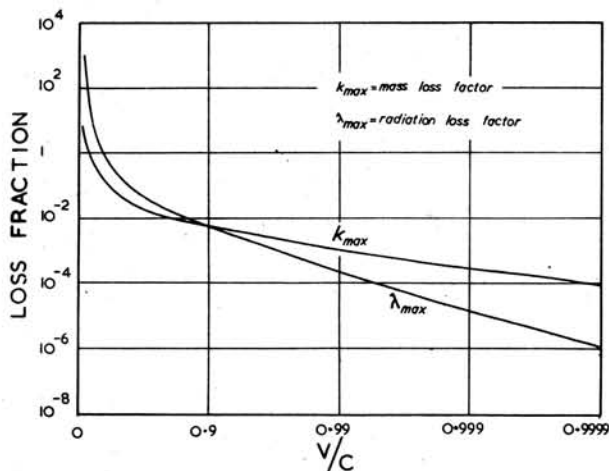


Fig. 2. Maximum permissible loss fraction for matter and radiation.

Table 1. Times available for $1g_0$ acceleration in a low density region. Proton chain

Material	t_s (years)	S(light years)
Aluminium	4.75	12.6
Copper	13.25	1,000
Diamond	15.75	3,550

of acceleration at $1g_0$ to half the trip distance and deceleration at $1g_0$ to the destination.

The effect of the decrease in the acceleration is shown in Fig. 3, where the distance travelled by the ISR is shown as a function of the ship time. It can be seen that the acceleration rapidly decreases to a point where no large increase in distance occurs over a period of time.

In the case of travel in a high density region the results are more favourable, and now even the deuterium chain may have some applicability. Table 2 shows some results, again for an initial acceleration of $1g_0$. The proton chain is now almost free of restriction and the limiting factor would be the extent of the high density region, rather than the vehicle structure.

Table 2. Times available for $1g_0$ acceleration in a high density region.

Material	t_s (years)		S(light years)	
	proton	deuterium	proton	deuterium
Aluminium	18.6	—	1.45×10^4	—
Copper	27.5	5.30	1.15×10^6	17.8
Diamond	30.0	7.75	3.80×10^6	64.6

However, the results, as Fishback noted, are very optimistic in that the factor $\log(B_m/B_0)$ is set equal to e ($=2.718$). The number is much larger than this value (because of the small value of B_0 and the large values of B_m required in practice, as will be seen in the next section) and, as it enters the equations in the denominator, the results will be much more restrictive than those above.

6. Magnetic Flux Density Limitations

This section investigates the magnetic intake of the ISR from the point of view of the magnetic fields that must be produced to collect sufficient interstellar material to propel the vehicle [12]. The problem of the confinement of ionised material by the use of a magnetic field which gradually increases towards a maximum at the vehicle is similar in many ways to that of particle confinement in fusion reactors which make use of a 'magnetic mirror' geometry, and indeed much of the physics is found to be equivalent. The obvious difference is that the mirror seeks to achieve complete confinement with zero particle transfer past the point of maximum field strength, while the intake attempts to compress a large volume of material into a dimension of the order of the reactor mouth without also causing a large particle reflection fraction. It is these 2 latter opposing requirements that cause the problems.

The initial part of the analysis, similar to that developed by Fishback, formulates the particle collection properties of the intake by applying 2 criteria. First, all particles with more than a certain amount of their initial momentum in the component transverse to the direction of motion of the

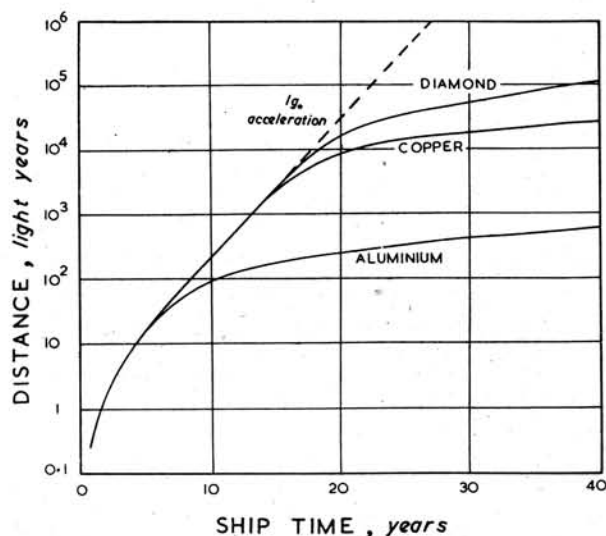


Fig. 3. Performance curve for a proton ISR in a low-density interstellar region.

vehicle are reflected by the magnetic field maximum, i.e. they are mirrored. Second, all particles which have an initial radius of gyration larger than a certain value are not injected into the vehicle powerplant, even if the particles are not reflected, i.e. they are not confined. These calculations allow values of the intake fractions of the ramjet to be estimated.

In order to allow investigation of the fundamental physical limits of the intake a constraint-free technology, which places no limit upon attainable flux densities or structural strengths, is considered. Assuming that a proton fusion reactor will become feasible (which is, of course, rather a large assumption in itself) allows a numerical value of the probable necessary particle collection rate to be derived, and this value can be used in conjunction with the intake fractions to determine the minimum possible intake dimensions.

The physical model used is one which the detailed configuration of the magnetic field is not important. The analysis is applicable to every situation provided only that the magnetic flux density increases in intensity from an initial value B_0 (the interstellar field) to a maximum value near the vehicle.

The minimum values of the intake radius, for operation in a high density region, are shown in Fig. 4. The scale used does not show the behaviour of the radius near $v/c = 1$ clearly. Above about $v/c = 0.9$ the radii decreases rapidly. Bussard showed that the ISR required an initial velocity component, and so the lowest velocity considered here has been set equal to $10^{-4}c$ ($v=30$ km/sec.). The values in Fig. 4 can be compared with those required by the frontal loading density criterion for $1g_0$ acceleration (Section 2), and it can be seen that the values given by the present calculation are much larger.

More serious, however, is the problem of the magnetic flux densities which are needed to confine the particles to the reactor. The values given by the analysis are shown in Fig. 5. Once again the scale used distorts the results at very high velocities, where the flux densities rise rapidly. Modern

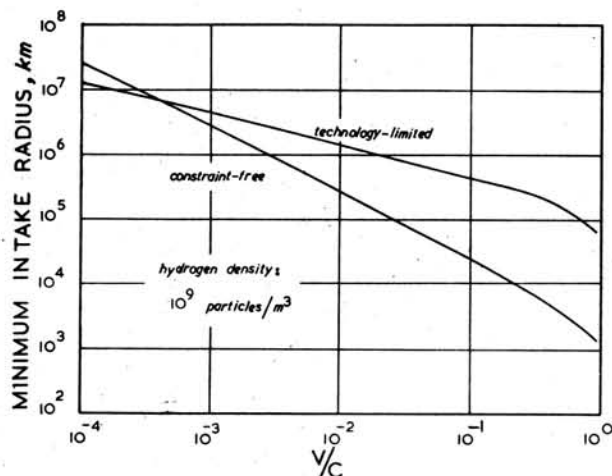


Fig. 4. Minimum intake radii in a high density region.

technology, of course, is only able to produce much lower levels of flux density. Intermetallic compounds (such as Nb_3Sn) have permitted the construction of superconducting solenoids with critical flux densities of the order of 100 tesla, and values of 1,000 tesla are probably feasible. Hence, the limits set by technical ability give the values of intake radius also shown in Fig. 4. These values are enormous.

7. Conclusions

From the problem areas discussed in the above sections, when considering the concept of an interstellar ramjet, a description of the technical abilities of a future civilisation which would be capable of building such a vehicle can be given.

It would be a civilisation capable of building and working with very high strength materials, producing and controlling (to a very fine degree) intense magnetic fields which project over very large distances, controlling the stability of plasmas in such fields and keeping the energy losses in these plasmas at a low level, and constructing efficient thermonuclear fusion reactors which run on the proton and deuterium chain reactions.

Science and technology, and the store of knowledge available to mankind, are advancing more rapidly than ever before in the history of our planet. The world as it is today

INTERSTELLAR BEACONS

Continued from page 16

There seems little doubt that some really advanced societies will from time to time endeavour to signal their presence. The methods used may be along the lines we have briefly considered. They could on the other hand be the products of an entirely different logic. In sweeping the heavens for such manifestations of other stellar communities we must be prepared for surprises. We should take seriously the desirability of consistent scanning of appropriate parts of the galactic space. It is highly unlikely we are alone in the Universe. We will not find our stellar neighbours if we do not look.

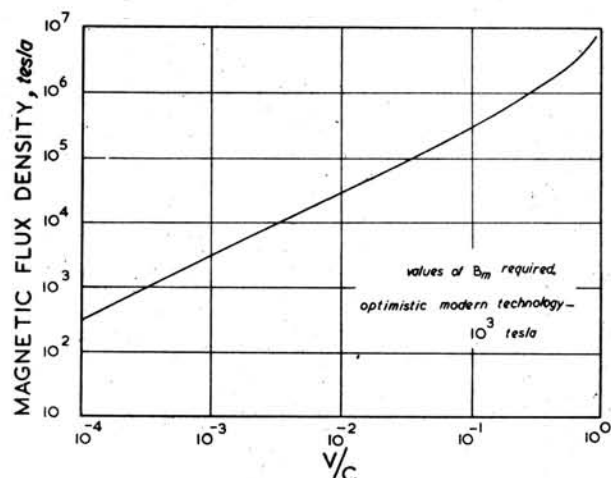


Fig. 5. Intake magnetic flux density necessary to give the maximum intake fraction.

was unimaginable at the turn of the century, when an essentially different science was being practised and taught.

Who can tell what the world will be like 70 years into the future? Perhaps our grandsons will be flying to the stars in diamond ships with magnetic sails.

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Previous articles in our New Frontiers Series appeared in the following issues of *Spaceflight*: April and September 1970, March and July 1971. Back numbers of issues published in 1971 only, are available from the Executive Secretary, price 50p. per copy including postage.

CONTROLLED THERMONUCLEAR FUSION FOR SPACE PROPULSION

By David Dooling, Jr.

Introduction

Numerous advanced propulsion techniques are now under study for manned interplanetary missions (orbit-to-orbit transfers). These range from the Nuclear Engine for Rocket Vehicle Application (NERVA), now under development, to exotic plasma and ion devices. The 2nd highest specific impulse theoretically possible is found in the fusion of atomic nuclei (total mutual annihilation of matter and antimatter would provide the theoretical maximum, but is so technically remote that it will not figure in this discussion).

There are 4 fusion reactions of primary interest to scientists. They involve deuterium (heavy hydrogen, one proton and one neutron), tritium (heavy-heavy hydrogen, one proton and 2 neutrons), and helium 3 (2 protons and one neutron), with helium 4 as their ultimate products (2 protons and 2 neutrons). They are favoured because, although they produce the least energy of all the thermonuclear reactions, they have the lowest ignition temperatures and are therefore easier to achieve.

Magnetic Confinement

Because of the temperatures involved, (in excess of 10^7 °K), no known material can contain a fusion reaction. Magnetic fields must be used to contain, compress, and therefore heat the plasma (ionized gas). Unfortunately, these fields, whether in pulsed or steady state devices, tend to deteriorate before reaching the break-even point (the right combination of temperature, confinement time, and ion quantity) as a result of plasma instabilities. Although much progress has been made recently, these problems have prevented fusion power from becoming a reality. They might not, however, prevent fusion from being used for space propulsion.

The design in Fig. 2 is called a mirror machine as it confines the plasma in a magnetic bottle stoppered at each end by magnetic mirrors which reflect the particles back and forth. As with many other controlled thermonuclear reaction (CTR) devices, it still is imperfect and manages to leak in one place or another. However, this might not hamper a CTR rocket as it must throw mass out to produce thrust. Thus, one mirror is deliberately weaker than the other and permits the plasma to escape.

The fuel for such an engine would be deuterium and helium 3 as the $D+He^3$ reaction yields helium 4 nuclei and protons, both charged particles. This permits confinement and controlled expulsion. A number of $D+D$ reactions would occur, resulting in uncharged neutrons, but it is felt that these can be minimized.

Maximum efficiency can be obtained from the magnets if they are super-cooled. However, in addition to reducing weight, it presents a cooling problem as much of the energy released is in the form of gamma radiation which produces heat when it is absorbed. Three cooling loops are provided for this. Two are closed and use liquid circulated through the structure and external radiators, the other third through the magnets and a cryostat. The 3rd one is part of the thrust augmentor and uses liquid $D+He^3$ in an open loop.

A CTR engine would produce only about 6 lb. of thrust, but at an I_{sp} of 600,000 sec. and 100 mw power output. This thrust level is very low and would increase the time required to leave orbit. A thrust of 220 lb, with a reduced I_{sp} of 20,000 lb-sec/lb, can be achieved by passing the heated $D+He^3$ mixture mentioned above through the engine nozzle,

$D + D + He^3 + N + 3.2 \text{ Mev}$
$D + D + T + P + 4.0 \text{ Mev}$
$D + T + He^4 + N + 17.6 \text{ Mev}$
$D + He^3 + He^4 + P + 18.3 \text{ Mev}$

Fig. 1. The four fusion reactions that could be used for space propulsion (Ref.2).

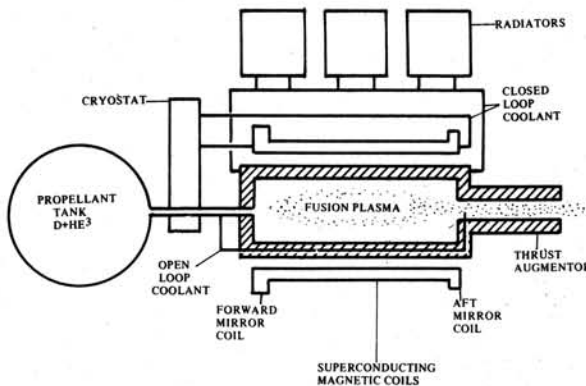


Fig. 2. Schematic of magnetic confinement fusion engine (Ref. 1).

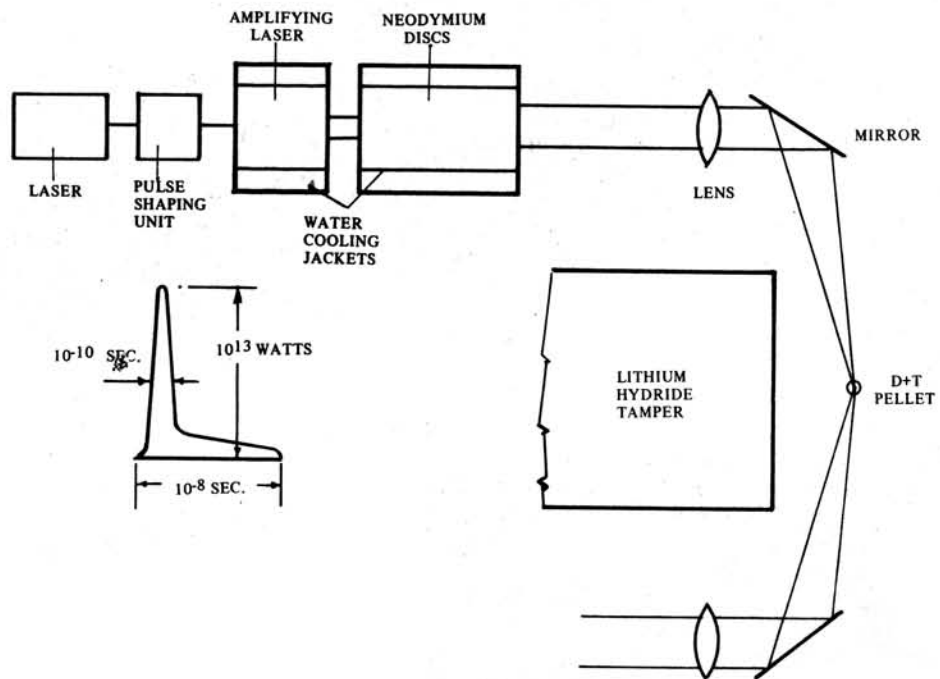
The exact operating mode for a CTR engine is, like CTR power generators, undetermined. It could be either steady state or pulsed (thrusting in cycles). Transfer times from Earth to Mars could be reduced to 14.9 days and, for Jupiter, to 127 days.

Laser Ionized Pellet

The state-of-the-art in lasers is approaching the point where it will be possible to trigger a thermonuclear reaction with a high energy, finely focused burst of light. This would produce not so much a controlled thermonuclear reaction as a semi-controlled H-bomb. Basically, a high powered burst of laser light is focused on a frozen $D+T$ pellet (chosen for its low ignition temperature) which, depending on the size of the pellet, produces an explosion on the order of 10 tons of TNT. In practice, it is much more complex.

The power level necessary is achieved by using lasers to 'pump' other lasers. First, one laser is fired and the light passed through a unit which shapes the pulse (Fig. 3). Another set of lasers is excited and, with the light from the first passing through, trigger a similarly shaped pulse. This in turn is passed through a series of neodymium glass discs which have been excited and then discharge a shaped pulse. The final light beam, which is 15 cm wide and carries a power density of 10^{17} watts/cm², is focused on the pellet through a fast aspheric lens. This system uses glass rod lasers and has been used just for preliminary studies.

Fig. 3. Schematic of laser-plasma fusion engine (Ref. 3).



However, when more fully developed, it is felt that gas lasers will be used for space propulsion versions of this system.

With efficient energy coupling, gas expansion velocities above 10^5 m/sec. can be produced. An I_{sp} on the order of 5×10^4 sec. can be produced as compared to 800 to 900 lb-sec/lb. for NERVA. If one pellet is fused per second, a thrust/weight ratio of 2×10^{-3} can be achieved for a vehicle weighing 110×10^3 Kg.

To shield the spacecraft from the 14 MeV neutrons released in the D+T reaction, an expendable lithium hydride tamper is placed on the base of the engine. This also provides the plasma with a recoil base. The chart (Fig. 4) shows the mass ratios (fuelled mass/empty mass) for minimum energy missions for both NERVA and the laser plasma engine. By increasing the mass ratio to 1.5, the round trip time to Mars can be reduced to as little as 4 weeks. This assumes a basic spacecraft weight of 250,000 lb. and a total propellant mass of 125,000 lb. Of this, only 125 lb. are D+T pellets, the

remainder being lithium hydride tamper.

A boiling potassium reactor, weighing up to 40,000 lb, could provide the 500 to 1000 kW of power needed to pulse the lasers. A closed loop variation of the laser plasma engine can be used to provide electrical power. In this scheme, the D+T pellets are fused in a pressure vessel. The energy from this fusion heats a vortex of liquid lithium on the tank walls. The remainder of the operation is much the same as other boiling metal reactors.

Conclusion

Both magnetic confinement and laser plasma engines present a great potential for reducing interplanetary transfer times. It is quite possible, in the light of recent advances, that either could replace NERVA before or shortly after it becomes operational. It is even more probable that the laser plasma engine will be used long before the magnetic confinement engine.

Acknowledgements

The author wishes to thank Dr. Krafft Ehrlicke of North American Rockwell Corporation for his assistance in supplying reference materials.

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2. Gough, William C. and Bernard J. Eastlund. 'The Prospects of Fusion Power,' *Scientific American*, Feb. 1971.
3. Lubin, Moshe J. 'Laser-Produced Plasmas for Power Generation and Space Propulsion,' *Astronautics & Aeronautics*, Nov. 1970.

MISSION	ΔV .FPS	MASSRATIO	
		NERVA	LASER
MOON	9×10^3	1.4	1.02
MARS	43×10^3	5	1.15
VENUS	50×10^3	6	1.17
MERCURY	102×10^3	42	1.37

Fig. 4. Mass ratios for minimum energy planet missions (Ref.3)

SKYLAB TRAINERS

Four Skylab trainers have been delivered to the Manned Spacecraft Center, Houston, for use in NASA's Skylab astronaut training programme which began late last year.

Two trainers — the Orbital Workshop and the Apollo Telescope Mount — left the Marshall Center, Huntsville, Alabama, on 1 October, aboard the NASA barge *Orion*. The barge arrived at the Houston space installation 11 days later.

Other Skylab hardware transported on the *Orion* include a Multiple Docking Adapter exterior 'shell' and a portion of an airlock mockup.

A completely outfitted Multiple Docking Adapter trainer was flown to MSC from Martin Marietta Corporation, Denver, Colorado, on 6 October aboard the 'Super Guppy' aircraft. The 'Super Guppy' later flew an airlock trainer from McDonnell Douglas Astronautics Company, St. Louis, to MSC.

The Workshop trainer is an engineering mockup which has been converted for its training role by the Marshall Center. It is a replica of the flight model and contains training versions of experiments and equipment. The Workshop model, about 48 ft. long and 22 ft. in diameter, was dismantled for shipment and re-assembled by Marshall Center personnel. The ATM is about 15 ft. long and 11 ft. in diameter.

Manufactured at Martin Marietta in Denver, the multiple docking adapter trainer contains a training version of the ATM controls and display console and certain experiments. The MDA is more than 17 ft. long and 10 ft. in diameter.

The Airlock trainer is a replica of the unit which provides a pressurized passageway between the MDA and the Workshop. The Airlock has a tunnel 5.5 ft. in diameter and almost 14 ft. long. It contains an airlock for extravehicular activity and the supply, distribution, and control centre for Skylab cluster atmosphere and thermal control.

SKYLAB STUDENT PROJECT

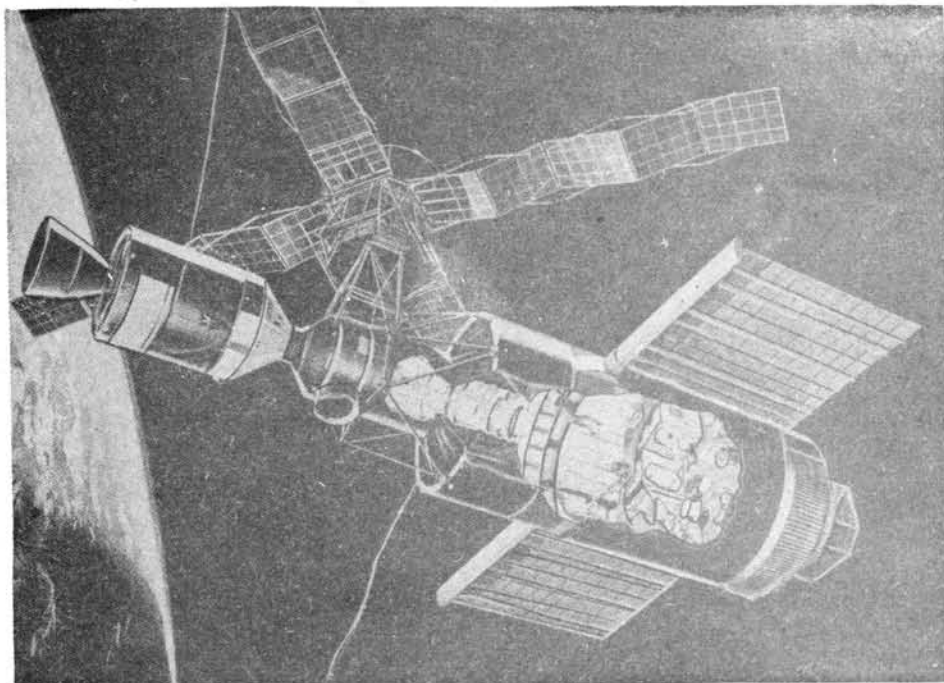
Management and operation of the Skylab Student Project will be carried out by The National Science Teachers' Association under contract to NASA. The programme is designed to stimulate interest in science and technology by directly involving students in space research. The 19-month cost-reimbursement contract, effective until 1 May 1973, is worth about \$39,000.

The National Science Teachers Association will provide the personnel, materials, facilities and services necessary for notification of the student and educational community of the opportunity and method of participating in Skylab. The Association will also develop procedures for evaluation of proposals based on educational value and provide certificates of participation and an awards system for entrants. Finally, the Association will develop plans and procedures for final selectees whose proposal ideas have been selected by NASA, and plan, organize and conduct a Skylab Student Education Conference for 25 national selectees at the Kennedy Space Center, Florida, at the time of the Skylab launch.

In this programme, activities proposed by students will be conducted by the astronauts on board Skylab in the course of Skylab missions. Experiments in crew recreation and other aspects of living in weightlessness will be considered as well as student scientific proposals.

A limited number of student proposed experiments will be selected for development by NASA from the 25 national selectees. The project is open to all students in grades 9-12 in US public, private, parochial, and US overseas schools.

Skylab is an Earth orbital space laboratory to be launched in 1973 to conduct scientific, technological, and biomedical investigations from the vantage point of space. The first manned mission will last up to 28 days or twice the duration of any previous US mission. The second and third 3-man missions are planned to last up to 56 days.



An enterprising step by NASA to promote science and technology in U.S. schools has thrown open the Skylab programme to student participation, see item above. Artist's impression shows the Skylab orbital workshop with the Apollo ferry docked at left.

McDonnell Douglas Corporation.

APOLLO 15 PARACHUTE FAILURE

Tests to determine the cause of the Apollo 15 parachute failure have been concluded with 2 items still listed as candidates. They are the fuel dump, which expelled approximately 6 lb. of monomethyl hydrazine (MMH) from the command module reaction control system, and the links which connect the suspension lines to the risers.

Apollo Spacecraft Program officials doubt that the exact cause can be determined, but corrective action will be taken on both effective with Apollo 16.

Tests have shown that MMH being dumped through a hot engine can result in tongues of flame from the thrusters which could affect parachute lines. Remaining fuel or oxidizer (nitrogen tetroxide) has been dumped shortly after main chute deployment. The dump will be eliminated in future missions, and the spacecraft will land with residual propellants aboard.

Flaws were detected in links on the one Apollo 15 parachute recovered. The parachute which failed was not recovered, but the possibility exists that enough of the links could have failed on it to permit collapse. The origin or cause of these flaws is not understood at this time. For this reason, the material for these links have been changed. The links were made of 4130 steel. In future links will be of Inconel, a nickel/steel alloy.

Tests eliminated the apex cover, or forward heat shield, as a reason for the parachute collapse.

NEW OCEAN SENSOR

A lightweight precision sensor to allow oceanologists to spot pollution and preserve ocean resources is under development in the United States. The 13 lb sensor, more sensitive to colour than the human eye, is called MOCS after Multi-channel Ocean Colour Sensor. It is being built by TRW's Electronic Systems Division for NASA's Langley Research Center and will be carried in aircraft and possibly in spacecraft.

As the sensor is flown over the ocean it scans a strip perpendicular to its line of flight, separating it into distinct blocks and identifying the colour of each block. Oceanologists can use this precise colour information to detect pollution, spot areas where fish are likely to be, and study marine biology.

Ocean colour information can tell oceanologists a great deal. Some tones of green show that plankton is present, offering the likelihood that fish are feeding in the area. One particular shade of blue has been named 'tuna blue'. Many brown shades are indicators of pollution.

Given repetitive, exact colour information from MOCS, oceanologists can chart trends in pollution and marine life for use in preserving and developing ocean resources.

The scanner records each strip in a fraction of a second, then returns to its start position to begin the next scan and thereby gives uninterrupted coverage of the ocean along the flight path.

MOCS output for each scan is a series of 150 spectral wavelength charts, each showing the precise colour for one square of the scanned strip. From an aircraft altitude of

25,000 ft, for example, a single MOCS scan would yield 150 wavelength charts, each of an area roughly 30 x 30 ft. From a spacecraft in a 500 n.m. orbit, each wavelength chart would cover an area one mile square, with the same precision.

Initial tests will be made aboard a twin-engine Aero Commander, operated for NASA's Advanced Applications Flight Experiment Program, at altitudes up to 25,000 ft. NASA is considering MOCS-type sensors for the Small Applications Technology Satellite (SATS) programme. Colour measurements during SATS flights could provide global coverage of the open oceans.

Multi-Channel Ocean Colour Sensor

	Spacecraft	Aircraft
Altitude	500 n mi	15,000 ft.
Ground resolution	1 X 1 n mi	30 X 30 ft.
Cross-track swath width	150 n mi	4500 ft.
Angular field of view	17.1 deg.	17.1 deg.
Spectral resolution	150 Å	150 Å
Spectral range	4000 - 7000 Å	400 - 7000 Å
S/N (5000 Å, scene irradiance, $1400 \frac{W}{M^2 - u}$)	110	110
Weight	12.6 lb.	12.6 lb.
Power consumption	6 W, 28 Vdc	6 W, 28 Vdc

X-RAY SOURCE IDENTIFIED

An X-ray source near the centre of the Galaxy may be identified with a visible object as the result of a new Skylark experiment. The rocket, carrying an X-ray detector, was launched as part of the UK national space research programme funded by the Science Research Council from the Woomera range, South Australia, at 12.30 hrs. local time on 27 Sept, carrying an experiment devised by Dr. K.A. Pounds of Leicester University.

Basically, the experiment was as follows: The position of the cosmic X-ray source (GX3+1) was already known to within 2 minutes of arc. The X-rays were observed at the time of their eclipse by the Moon on 27 Sept. so that the exact time of disappearance would define its source in one co-ordinate 500 times more accurately. In order to ensure that the occultation would take place during the rocket's 4 minute observing time the launch was timed for a 1 minute window. If this had been missed there was a second window 44 minutes later.

The X-ray counter looked at the source sideways from a Sun-pointing stabilised Skylark rocket (SL1002). The standard magnetic roll control system using the Earth's magnetic field lines as a reference could not be used because at the time of the occultation the Sun was too nearly aligned to the Earth's magnetic field. For this reason the vehicle employed a special system using the strong X-ray source in Scorpius as a roll reference. The technique had already been used to improve control accuracy but this was the first occasion that Scorpius had been employed as the only reference.

SATELLITE DIGEST – 42

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see February 1969 issue, page 66.

Continued from December issue p.480.

Name and designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and origin
Explorer 44 1971-58A	1971 Jul 8.96 8 years	Cylinder + 4 panels 117.94	0.58 long 0.76 dia	433	632	51.06	95.23	Wallops Station Launch Area 3A Scout B USN (1)
Meteor 9 1971-59A	1971 Jul 16.07 60 years	Cylinder + 2 panels + antenna	5 long? 1.5 dia	615	642	81.20	97.31	Plesetsk Vostok USSR (2)
1971-60A	1971 Jul 16.45 5 years	Cylinder 2000?	8 long? 1.52 dia	488	508	75.00	94.59	WTR Thrust Augmented Thor Agena D USAF
Cosmos 429 1971-61A	1971 Jul 20.42 12.9 days (R) 1971 Aug 2.3	Sphere-cylinder 4000?	5 long? 2.44 dia	202 179	252 258	51.76 51.76	88.98 88.81	Tyuratam-Baikonur USSR (3)
1971-61E	1971 Jul 20.42 15 days 1971 Aug 4	Sphere?	2 dia?	185	360	51.81	89.89	Tyuratam-Baikonur USSR (4)
Cosmos 430 1971-62A	1971 Jul 23.46 12.7 days (R) 1971 Aug 5.2	Sphere-cylinder 4000?	5 long? 2.44 dia	199 188	305 267	65.41 65.40	89.54 89.05	Plesetsk USSR (5)
1971-62F	1971 Jul 23.46 16.74 days 1971 Aug 9.20	Sphere?	2 dia?	181	237	65.41	88.68	Plesetsk USSR (6)
Apollo 15 1971-63A	1971 Jul 26.57 12.30 days (R) 1971 Aug 7.87	Cone-cylinder + antenna + 2 booms 30343.12	10.37 long 3.91 dia	168 200	170 572080 Selenocentric orbit	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (7)
Saturn AS-510 1971-63B	1971 Jul 26.57 3.30 days 1971 Jul 29.87	Cylinder 13987.21	18.69 long 6.60 dia	168 200	170 572080 Lunar impact	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (8)
Apollo LM-10 ascent stage 1971-63C	1971 Jul 26.57 4.36 days 1971 Jul 30.93 1971 Aug 2.72 0.41 day 1971 Aug 3.13	Irregular cylinder + 2 tanks + 2 antennae 2127.38	2.52 long 3.13 dia 3.76 high	168 200	170 572080 Selenocentric orbit Lunar landing Selenocentric orbit Lunar impact	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (9)
Apollo sub-satellite 1 1971-63D	1971 Jul 26.57 Indefinite	Hexagonal cylinder + 4 booms 35.61	0.79 long 0.36 dia	168 200	170 572080 Selenocentric orbit	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (10)
Apollo LM-10 descent stage 1971-63E	1971 Jul 26.57 4.36 days 1971 Jul 30.93	Octagon + cone + 4 legs + cylinder 2802.79	1.57 long 3.13 dia	168 200	170 572080 Selenocentric orbit Lunar landing	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (11)
Apollo LRV 1 1971-63L	1971 Jul 26.57 4.36 days 1971 Jul 30.93	Irregular frame + 4 wheels + boom + antenna 208.66	3.10 long 2.29 dia 1.14 high	168 200	170 572080 Selenocentric orbit Lunar landing	32.57 33.2	87.87 26320	ETR LC 39A Saturn 5 NASA (12)
Molniya 1T 1971-64A	1971 Jul 28.15 5 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	468	39254	65.37	704.99	Plesetsk USSR (13)

Cosmos 431	1971 Jul 30.36	Sphere-cylinder	5 long?						Tyuratam-Baikonur
	11.91 days (R)		2.44 dia	194	257	51.77	88.95		
1971-65A	1971 Aug 11.27	4000?							USSR

Supplementary Notes:

(1) Solar Explorer C monitors solar ultra-violet and X-radiation in studies of solar physical processes and solar effects on shortwave communications, provides continuous solar radiation observations during manned space flights and measures, on command, stellar X-radiation. Power is supplied by 4 symmetrically-located, 0.53-metre long, 0.18-metre long, 0.18-metre wide solar cell panels deployed from Explorer 44's midsection after 3rd-stage burnout. Onboard attitude control system maintaining satellite spin rate at 60 rpm and spin axis aligned $\pm 2^\circ$ of the Sun uses solar sensors activating 3 attitude spin subsystems utilising sensor-commanded low-thrust liquid anhydrous ammonia propellant thrusters, 2 redundant attitude control subsystems sharing a common internal toroidal propellant tank with solar sensor-command pulses allowing ammonia vapour to pass through 2 sets of solenoid valves, latching valves and nozzles to precess Explorer 44's spin axis to within $\pm 2^\circ$ of the spacecraft Sun line, together with 2 redundant spin replenishment systems consisting of solenoid valves, latching valves and nozzles using prime attitude control system propellant tank but capable of accepting ground commands as required, while a 3rd attitude control subsystem and 3rd spin replenishment subsystem share a spherical hydrazine propellant tank, each subsystem containing latching valves, solenoid valves, catalyst beds and nozzles. Spacecraft realtime 3-year nominal lifetime telemetry subsystem transmits continuously at 137.710 MHz at 0.5 watts for tracking and realtime data transmission to Naval Research Laboratory ground stations, and at 136.380 MHz at 3 watts for onboard memory store experiment data transmissions for about 5 min. each orbit to NRL's Blossom Point, Maryland data reception facility, realtime telemetry subsystem using linearly-mixed output of 5 voltage-controlled subcarrier oscillators phase-modulating the transmitter, the oscillators being frequency-modulated by their individual inputs of pulse amplitude modulation, analog and pulse code modulation data while memory store data transmission is a PCM/PM subsystem. Onboard instrumentation includes 7 ionisation chambers measuring solar X-rays between 0.5 to 3, 1 to 8, 8 to 16, 1 to 20 and 44 to 60 Angstroms wavelength. An ionisation chamber measuring solar electron temperatures between 1 to 5 Angstroms, 2 ionisation chambers monitoring solar Lyman alpha radiation between 1080 to 1350 Angstroms, 2 ionisation chambers monitoring solar ultraviolet radiation between 1225 to 1350 Angstroms, an ionisation chamber measuring solar ultraviolet continuum flash spectra between 1500 to 1700 Angstroms, an ionisation chamber measuring solar hard X-ray continuum spectra between 0.1 to 1.6 Angstroms, a parallel-plate ionisation chamber measuring solar X-rays between 0.5 to 3 Angstroms, a scanning ionisation chamber measuring solar Lyman alpha bursts between 1080 to 1350 Angstroms, 2 ionisation chambers each aligned 5° to the spacecraft-Sun line measuring background X-radiation levels between 0.5 to 3 and 1 to 8 Angstroms, a scintillating crystal and photomultiplier monitoring hard solar X-rays with energies between 20 to 150 Kev between 0.1 to 0.5 Angstroms, a lithium fluoride photometer measuring excitation of the solar F-layer between 170 to 600 Angstroms, a large-area proportional counter measuring stellar X-radiation variations between 0.5 to 15 Angstroms, and a thermistor measuring anti-solar satellite surface temperatures. Following nominal launch all systems commenced operations and high-quality telemetry was received at ground stations. Explorer 44, also named Solar Radiation 10, was the 58th Scout satellite launch and 47th successful Scout satellite mission.

(2) 15th operational Soviet meteorological satellite maintains global satellite TV observation capability of Earth's weather, cloud cover, ice and snow fields and thermal emission from Earth's dayside and nightside surface and atmosphere. Constantly solar-oriented solar panels supply power and gravity gradient stabilisation maintain attitude control. Meteor 9 carries instrumentation measuring Earth's

atmospheric infrared emissions from which accurate temperature profiles of atmospheric layers are determined; initial results from this experiment indicate that measurements of vertical distribution of temperature between ground level and 35 km altitude are possible.

(3) Orbital data at 1971 Jul. 22.6 and Jul. 24.2.

(4) Capsule ejected from Cosmos 429 at about 1971 Aug. 1.

(5) Orbital data at 1971 Jul. 24.4 and Jul. 26.5.

(6) Capsule ejected from Cosmos 430 at about 1971 Aug. 4.

(7) Astronauts David R. Scott, commander, Alfred M. Worden, command module pilot and James B. Irwin, lunar module pilot, flew Apollo 15 on a 295 hr. 12 min. long mission to perform a manned lunar landing and return to Earth. For a report on this mission see Baker, D., 'Expedition to Hadley-Apennine', *Spaceflight*, 13, 358. Apollo 15 was the 23rd US manned orbital flight, 25th US manned space mission, 9th manned Apollo flight, 7th manned space flight to the Moon and 4th manned lunar landing mission. Orbital data at 1971 Jul. 26.58, Jul. 26.70 and Jul. 29.84.

(8) 25th Saturn launch, 10th Saturn 5 orbital mission, 8th Saturn manned mission and 3rd Saturn S-IVB stage to impact Moon: 1971-63B attached to 1971-63A until 1971 Jul. 26.71 and impacted Moon at approximate astronomical selenocentric latitude 1° South, longitude $11^\circ 52'$ West at Jul. 29.87. Orbital data at 1971 Jul. 26.58, Jul. 26.70 and Jul. 29.87.

(9) 8th Lunar Module orbital flight, 7th LM manned mission, 4th LM lunar landing mission and 3rd space object to land on the Moon at different locations. 1971-63C attached to 1971-63B until 1971 Jul. 26.76, attached to 1971-63A until Jul. 23.84, landed on the Moon at Jul. 30.93, launched from the Moon at Aug. 2.71, redocked with 1971-63A at Aug. 2.80 jettisoned at Aug. 2.97 and impacted the Moon at Aug. 3.13. Orbital data at 1971 Jul. 26.58, Jul. 26.70, Jul. 29.84, Jul. 30.93, Aug. 2.75 and Aug. 3.14.

(10) First Apollo subsatellite, first scientific satellite launched from a manned spacecraft and first scientific satellite injected into selenocentric orbit from a manned spacecraft was ejected from Apollo SM-111's scientific instrument module and carries boom-mounted S-band transponder, transmissions from which provide precise tracking data permitting lunar gravitational field measurements and determinations of gravitational anomalies, telescope particle detectors and spherical electrostatic particle detectors measure dynamics of Earth's magnetosphere at lunar distances, interaction of plasma with the Moon and measure solar flare emissions, and a 1.52-metres long boom-mounted biaxial fluxgate magnetometer measures lunar physical and electrical properties and interaction of plasma with the Moon. Spring-ejected out of plane at 1.22 metres per sec. with a spin rate of 140 rpm, boom-deployment reducing spin rate to about 12 rpm, satellite uses solar cell arrays supplying 25 watts during dayside transits and recharging an onboard battery used during lunar nightside transits. Attached to 1971-63A until 1971 Aug. 4.83. Orbital data at 1971 Jul. 26.58, Jul. 26.70 and Aug. 4.85.

(11) Attached to 1971-63C until 1971 Aug. 2.71. Orbital data at 1971 Jul. 26.58, Jul. 26.70, Jul. 29.84 and Jul. 30.93.

(12) Attached to 1971-63E until 1971 Jul. 31.58. Orbital data at 1971 Jul. 26.58, Jul. 26.70, Jul. 29.84 and Jul. 30.93.

(13) 18th communications satellite in Orbita network.

Decays:

1971-56A decayed 1971 Aug. 6, lifetime 52 days (R).

Amendments:

1971-23C, lifetime is 20.54 days, descent date is 1971 Apr. 17.00.

Cosmos 404, 1971-27A, lifetime is 0.04 day, descent date is 1971 Apr. 5.64.

San Marco 3, 1971-36A, lifetime is 8 months.

Cosmos 427, 1971-55A, lifetime is 11.8 days (R), descent date is 1971 Jun. 23.2.

ASTRONOMICAL NOTEBOOK

By Prof. J. S. Griffith

The Atmospheres of Mars and Mercury

The absence of fine dust in the Martian atmosphere and the upper limit of the atmosphere of Mercury are discussed.

Using the 100-in. Mount Wilson telescope for observations of Mars and the 24-in. lunar and planetary telescope for observing Mercury, Ingersoll [1] estimated the surface pressure of Mars (if the atmosphere is pure carbon dioxide) to be 5.6 mb (in agreement with observations from the Mariner occultation experiments). For various models of Mercury's atmosphere the upper limits on the surface pressure were found to be 0.4 mb for H₂, 0.41 for N₂, 0.28 for CO₂, 4.3 for He, 5.8 for Ne, 0.65 for Ar. Thus the evidence that Mercury is devoid of any significant atmosphere is strong and the author's measurements indicated that the optical depth is small even at the shortest wavelengths. This small optical depth indicated that the Martian atmosphere is almost transparent, and that the 'blue haze' is a surface phenomenon. The small optical depth combined with the darkness of the surface indicates that the surface of Mars is extremely dark in the ultra-violet. Polarization studies indicated that absence of fine dust in the Martian atmosphere.

REFERENCE

1. Ingersoll, A.P., 'Polarization measurements of Mars and Mercury: Rayleigh scattering in the Martian atmosphere' *Astrophys. J.*, **163**, 121 (1971).

Radio observations of Venus

Maps of the planet Venus and possible models for its atmosphere are derived from observations made with the Cambridge One-Mile radio telescope.

The Mariner and Venera space probes have not yet fully disclosed the nature of the surface of Venus. Radio and radar techniques can penetrate through the cloud layers to the surface. The operation of the One-Mile telescope is described in reference [1], and its use to observe Venus is reported in reference [2]. The surface pressure is 110 ± 15 atmospheres, with a surface temperature of $790 \pm 20^\circ\text{K}$. Approximately 0.4% water vapour is present in the lower atmosphere, and it appears that temperature variations of up to 50°K can occur over the surface. No large-scale distribution of gas is likely within the atmosphere of Venus.

A bright feature was observed on the eastern side of the disc, but no explanation is offered.

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1. Elsmore, B., Kenderdine, S. and Ryle, M., *Mon. Not. Roy. Ast. Soc.* **134**, 87 (1966).
2. Hall, R.W. and Branson, N.J.B.A., 'High Resolution Radio Observations of the planet Venus at a wavelength of 6 cm., *Mon. Not. Roy. Ast. Soc.*, **151**, 185, (1971).

The Satellites of Saturn

Spectrophotometric observations of 5 of Saturn's satellites at ultraviolet, visible and near-infrared wavelengths have been analysed to give information on the conditions of the satellites.

To an observer on the Earth, the satellites of Saturn appear to be faint stars. Using the Mount Wilson 60-in. and 100-in. telescopes the spectral reflectivities of Iapetus, Rhea, Dione and Tethys were observed [1]. Titan, the largest and brightest satellite, was observed at different

times, together with the spectra of the central yellow equatorial band of Saturn.

It was found that the reflection spectra of Rhea, Dione, Tethys and the bright side of Iapetus are similar and resemble what is expected of water or ammonia frost spectra between 0.4 and 1.1μ . They do not resemble common ferrosilicate spectra and are also different from the spectra of the rings, implying different surface materials or processes in the rings.

Titan's spectra was different, closely resembling the spectrum of Saturn's equatorial band. It appears that Titan's atmosphere is much thinner than Saturn's.

Variations in brightness with orbital phase for all the satellites save Titan suggests synchronous rotation. It is possible that about one third of the surface area is composed of dark material (silicates?).

REFERENCE

1. McCord, T.B., Johnson, T.V., and Elias, J.H., 'Saturn and its Satellites: narrow-band spectrophotometry ($1.3\text{--}1.1 \mu$)', *Astrophys. J.*, **165**, 413 (1971).

The Neptune - Pluto System

A numerical integration of the orbit of Pluto over $4\frac{1}{2}$ million years has shown that the stability of the Neptune - Pluto system is assured.

The orbital periods of Uranus, Neptune and Pluto are very nearly in the ratio 1:2:3. Such near commensurabilities give rise to long period perturbations of moderately large amplitude. Pluto's closest approach to the Sun brings it within the orbit of Neptune, and the possibility of a close approach has led various people to test the manner in which the planets move in their orbits by performing numerical integrations. A one million year integration has recently been completed, but this effort has now been surpassed by a 4 and half million year integration [1] from 2.1 million years B.C., to 2.4. million years A.D. Using a 500-year integration step-size in a 4th order Runge-Kutta routine it was found that the argument of perihelion librates about 90° with an amplitude of around 24° and a period of around 4 million years and that the closest approach of Neptune and Pluto is at a distance of around 17 astronomical units. The minimum distance of approach of Pluto to Neptune is increasing, as is presumably the stability of the system. It seems that the libration did not start more recently than the stabilization of the planetary masses shortly after the formation of the solar system.

Pluto may have been manoeuvred into the commensurability configuration by forces immediately following the formation of the solar system, (the gravitational effects of the changing masses of the planets and collision of gas and solid matter with the proto-Pluto); the commensurabilities may have aided the formation and aggregation of the planet; there may have been more than one protoplanet or of smaller size, and the others were ejected out of the solar system by close encounters or collided with Neptune. 'One cannot help wondering whether this remarkable pair (Neptune-Pluto) holds any other surprises'.

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The Origin of Small Interplanetary Particles

By observations of the changes in brightness with phase of 3 asteroids it may be possible to decide whether the small interplanetary particles are of cometary or asteroidal origin.

Observations at the McDonald Observatory of the asteroids (4) Vesta, (6) Hebe and (110) Lydia have been analysed to determine the photographic magnitude and reddening with phase, together with the period of rotation and, hopefully, the orientation of the axis of rotation (1).

There is a pronounced nonlinear increase in brightness as the phase decreases from 8 degrees to zero (in the opposite direction to that of the Sun, as seen from the Earth). This has been named the opposition effect. Laboratory studies indicate that the opposition effect is due more to texture than to composition.

If the opposition effect proves to be the same for faint asteroids (presumably collision products) as for the brighter ones (formed by accretion?) and independent of distance from the Sun, then a possible explanation is that different asteroids, which may have different compositions, have had the same bombardment by small particles and by the solar wind. This would indicate a cometary rather than an asteroidal origin of the small particles.

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Disk Shaped Stars

Three anomalous sets of stellar observations are explained with the aid of postulated disk-shaped stars.

D. S. Hall and his co-workers (3) have succeeded in explaining the peculiar observations of 3 eclipsing binaries by postulating the existence of disk-shaped luminous objects. (1), (2). For the extremely young eclipsing binary BM Ori, the secondary star appears to be nearly at the Roche limit, with an intrinsic red light combined with blue light from the blue primary, scattered by dust particles around the disk shaped secondary.

For the 2nd binary (HS Her) the observations are explained by the evolution of an initially disk-shaped object into a fairly normal star, but leaving an opaque cloud within the Roche limit of the secondary. HS Her is about 100 times older than BM Ori. The 3rd binary (RT Lac) is explained by the larger star being surrounded by an opaque disk which is cool (black) so does not contribute to the luminosity. In 1918 the secondary after filling its Roche lobe spilled material to the primary star and its associated disk system. This impact led to an upset of the equilibrium with radiation escaping and the formation of a hot spot on the disk. This, as the system rotated, led to asymmetric eclipses and unequal maxima. The bright spot appears to make one revolution in about 15 years.

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Technetium Stars

As all isotopes of technetium (Tc) are unstable with half lives of the order of a million years or less, the observation of Tc in stellar atmospheres implies recent formation of the element.

These stars show other heavy elements characteristic of nucleosynthesis by the s process [1]. A list of 18 cool, heavy-element variable stars is given in reference [2], and it is pointed out that heavy element stars without Tc must either have ceased to transport the products of s process reactions from their interiors over a million years ago, or to have a transportation process that occupies over a million years to reach the atmosphere. Mass lost from the heavy-element variables will enrich the interstellar medium, and may be a significant source of heavy-element enrichment in the Galaxy.

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The Origin of the Galactic Halo

The question of whether the halo of the Galaxy was formed by gravitational collapse of a gaseous proto Galaxy or by violent ejection from the Galactic nucleus is discussed.

Surrounding the flattened disc shape of the spiral arms of our Galaxy with their stars, dust and gas is a spheroidal region — the Galactic halo. The halo contains globular clusters and RR Lyrae (and other Population II) stars, with a corona of gas and relativistic particles. The halo is possibly a remnant of the proto-cloud whose collapse formed the Galactic plane, with the halo objects either being formed during the rapid-collapse phase [1] or condensing after the collapse [2]. Another Hypothesis [3], [4] is that the halo was formed by matter sprayed out from the nucleus of the Galaxy by violent explosive events. In ref. [5] these various ideas are discussed. It is commented that the halo constitutes at least 5% of the Galactic mass (about 10^{10} solar masses), and that the question of deciding between the 2 theories of origin may be decided when it is known whether the Galactic halo is homogeneous entity of objects with physical properties distinct from those of the members of the disk. It is known that properties of halo objects show considerable positional dependence, so the indication is that properties of halo objects at one extreme blend with those of the disk. This lack of a clear cut-off between halo and disk objects seems to lend to serious problems with the ejection hypothesis.

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SOCIETY NEWS

Symposium on 'Sounding Rockets and Experimental Results'

About 100 participants attended the 2nd Symposium on 'Sounding Rockets and Experimental Results' held in the Large Physics Theatre of University College, London on 15-16 September, 1971. About one-third of the participants were from overseas, representing 8 different countries.

The meeting continued one held about 18 months ago at the University of Cardiff, with no lack of papers. Indeed, a typical complaint of the delegates was that the 2-days allocated was insufficient and it would have been better to have had a 3-day event.

As at the previous symposium, the programme was divided into 4 sessions, the early ones dealing with the technological aspects of sounding rockets and the latter ones with scientific payloads and results so that the whole spectrum of sounding rocket launchings, performance, preparing payloads and obtaining results was covered. It is, of course, difficult with so many papers of such interest, to comment on those which had the greatest interest.

First Session

The first paper of the session, by Mr. D. Eaton, Head of Sounding Rockets in ESRO, summarised the ESRO sounding rocket activities from 1964-1971 and, though there is a current likelihood that these will be discontinued in future. Very interesting slides showed both ESRANGE and the rocket range in Sardinia besides the various types of rockets used by ESTEC. It was interesting to note that twice as many Skylarks as Centaur rockets are now being used by ESRO. For the future, Mr. Eaton considered that it was the desire of scientists to go heavier and higher using ACUs.

The session also included a paper by Mr. P. R. Malcolm of the Weapons Research Establishment of Australia about sounding rockets activities there. This was followed by a description of the Andoya Rocket Range by Mr. Gunderson of the Norwegian Science Research Council. This range was opened in 1962. Some 84 launchings had been made since then; being a sea range, has a large dispersion area available.

Dr. J. Martin-Lof of Sweden discussed the 2 systems for tracking sounding rockets which are currently available, i.e. the NASA interferometer system and the Norwegian/Danish system - which was the subject of this paper. He considered that, in tests, the altitude determination could be made to within $\pm 15\text{m}$ and 1° in angle. The discussion on this paper brought out some interesting observations on the accuracies of radar V. slant range equipment, which continued into the coffee break.

Dr. R. Klett of the Mobile Raketenbasis of DFVLR started the second part of this session with a description of a proposal for a ship-board rocket launch facility. He explained that the German Ministry of Scientific Research have available a 25,000 ton research ship which is fitted with nuclear motor reactors and, with the aid of an excellent model of this ship, explained how a launcher for sounding rockets would be fitted at the forward end. The ship was being fitted with tracking radars and telemetry, so that sounding rockets could be launched from any location throughout the world. This indeed was a most interesting possibility which aroused the interest of all present at the meeting.

On the nautical theme, Mr. Zdarsky From DFVLR gave a description of the water recovery system for sounding rocket payloads which they had developed. Slides showed the tests on this system in which payloads were dropped

from 19,000 feet and the inflatable taurus kept the payload floating in the sea until such time as it was located by aircraft and recoverable by ship.

Mr. Cade of CNES produced an excellent film of static firings, carried out at the French range near Bordeaux, to test payload parachutes which have been developed for recovery purposes. This film also showed the Erodin rocket being launched and its payload being recovered from a height of 200km from the sea.

Also on parachutes, Mr. S. B. Jackson, whose time had been severely curtailed by the late running of this session, expounded on the types of parachute which could be used for high altitude work and payload recovery systems. He considered the cruciform parachute was the best for high altitude work.

Second Session

The opening paper, given by Mr. J. W. Furst (BAC), outlined improvements in the performance of the Skylark rocket which could increase apogee and experimental time. One proposal is the Raven XI which will employ a new propellant and charge design in the existing motor case. This has a regressive thrust profile which gives a high launch acceleration to minimise wind sensitivity. A goldfinch-boosted Raven XI will carry a payload mass of 200kg to an apogee of 420km.

A second proposal, tentatively known as Skylark 8, involves the combining of 2 RPE developed motors, the first stage being Stonechat (92cm dia) and the second, Waxwing (71cm dia). This system would lift a 200kg payload to 1,000km altitude.

The next paper, by Mr. W. T. Fisher (BAJ), dealt with the need to keep the costs of meteorological rockets to a figure of around £1,600 per shot. This could be achieved by using a variable thrust packaged liquid motor as a recoverable first stage and solid propellant powered dart as the second stage.

Dr. N. Simmons raised the question of how the new Skylark rockets would meet specific experimenters requirements. In reply, Dr. P. Rothwell (Southampton University) stated that there was continuing interest in auroral and magnetosphere phenomena up to around 400km altitude and the advantage of a sounding rocket against a satellite for this purpose was that it gave a vertical profile and that it enabled a particular moment in time to be chosen.

Then followed a paper by Mr. D. S. Carton which discussed the cost-effectiveness of solid and liquid propellant rockets, against their achieved initial acceleration.

The next paper was presented by Mr. J. A. Bosgra (NLR) on a rudder actuating system for attitude control during the ascent phase of a spinning rocket. The rudders have a sinusoidal motion in phase with the roll rate so that they impart a horizontal velocity in the direction required to reduce dispersion. Then followed a paper by Mr. G. Boersma (NLR) which investigated the coning motion of rocket payloads at high altitude, where there is virtually no air density. The effect of launch elevation, winds, misalignments and magnus forces on the coning motion was considered.

Mr. P. Starling (ESRANGE) raised the question of the reliability of the rudder controlled system since, if a failure occurred in flight, the rocket could fall outside the range boundaries. Mr. Bosgra replied that the system had yet to be flight-tested. Mr. Eaton (ESTEC) added that there was an existing problem of dispersion with short burning motors

which was difficult to cope with. Mr. Furst (BAC) commented that statistics would have to be applied for this source of failure.

The final paper of this session given by Mr. T. MacPherson (University of Saskatchewan) was concerned with the effect of experiment deployment on vehicle coning motion in space. It proposed a simplified method of defining the coning motion by a combination of theoretical analysis and actual ground test measurements of the pitching moments.

Third Session

By the beginning of the second day, the majority of papers on sounding rockets technology had been read and the theme of the symposium swung towards payload technology and scientific results, with the 3 papers which started the first session on electronic and ACU systems available for sounding rockets.

Mr. P. Stinchcombe gave an explanation of techniques for using pulse modulation for attitude control, followed by a paper and demonstration on the actual equipment of a PCM system for sounding rockets which has been developed in Norway and was read by Dr. J. Troim of the Norwegian Science Research Establishment.

Mr. C. Poher of CNES then showed a most interesting film of the Cassiopeia system which had been developed in France for use with the Erodin rockets. A very interesting contention of Mr. Poher was that CNES considered that sounding rockets were better for uv astronomy than satellites: they considered about 70 of these astronomical payloads would be launched.

Dr. R. Wilson of the Culham Laboratory heralded the start of the scientific result papers with an interesting account on the study of the solar corona.

The session was completed with a paper ready by Mr. W. B. McPheeters on the various types of Black Brant rockets made in Canada, and another on the environmental testing of sounding rocket payloads by Mr. M. Goose (BAC). The latter demonstrated the care and precision required in the preparation of payloads and the amount of environmental testing required to ensure that they will work correctly.

Fourth Session

The afternoon session of the last day was entirely concerned with papers from experimenters from British Universities.

Mr. E. Williams University College Wales, and Mr. R. A. Henderson of University College, London, both dealt with Skua sounding rockets and the meteorological and scientific results obtained with them, while the value of Petrel rockets used by the University of Southampton to measure charge particles were described by Dr. G. J. Jenkins;

The other rocket in the British sounding rocket series — the Skylark — was used for X-ray measurement experiments described by Dr. A. M. Cruise of University College, London, and also in the Cosmic Ray experiments expounded upon by Dr. D. J. Adams of the University of Leicester.

Summary

There is no doubt that the symposium was enjoyed by all delegates, especially those members from overseas countries who had taken the trouble to travel considerable distances to be present. The majority of overseas visitors were extremely keen on the symposium as there are few similar forums in

which sounding rocket technology and scientific results can be discussed.

New Film Programme

An audience of over 160 members and guests attended the Society's Meeting in London on 16 Sept. 1971 when a programme of new films was featured.*

The first to be screened was *Spaceport U.S.A.* which showed the impressive facilities at Cape Kennedy, actually *in situ* by those fortunate enough to be on the recent Charter Flight to witness the Apollo 15 Launch. Breathtaking views of the Crawler-Transporter and Vertical Assembly Building were included, but left unanswered was the question of how these facilities will best be utilised with the phasing out of the Saturn V Rocket and the beginning of the Shuttle.

The second film *The Moon-Old and New* afforded a very good review of our satellite, with a run-down of the many additions to our knowledge which have taken place between the flights of Ranger 7 and Apollo 12, including a number of photographs showing the structure of Lunar Rock samples. It closed with a brief resume of investigations which many scientists would still like to undertake.

Mariner-Mars 69 was a documentary on the flights of Mariner 6 and 7 to the planet Mars in 1969, presenting the objectives of the mission in an animated form and photographic results in great detail, and of considerable interest.

The final film, *Apollo 14 — Mission to Fra Mauro*, was a documentary record of the flight similar to the earlier Apollo films already screened at meetings of the Society. The spectacular 216 hour long flight of 'Antares' and 'Kitty Hawk', during which Shepard and Mitchell touched down on the Fra Mauro region — originally scheduled as the prime landing site for the aborted Apollo 13 — while Roosa orbited in the CM above, was outstanding both for its success and its spectacular photography, and showed once again that the Apollo flights lack nothing in excitement.

All in all, it was a programme greatly enjoyed by the audience, many of whom stayed on for some time afterwards for impromptu discussions, to see a model illustrating a proposed Skylab Soyuz docking, and to examine a wide range of literature on display.

**These 4 films will be reviewed in detail in a later edition of Spaceflight. Prints are available on loan from the Society, from whom a film list can be obtained on request, enclosing a foolscap reply-paid envelope.*

The Promise of Space

More than 400 members and guests attended the special presentation by Arthur C. Clarke, a former Chairman of the Society, in London on 30 Sept. 1971. Mr. Clarke took as his theme the impact of Space on human society and showed extracts from his recently completed TV film, *'The Promise of Space'*.

He began by saying that there were 3 stages in the reactions to any new idea.

- (1) it can't be done;
- (2) it's not worth doing, and
- (3) it's what I've been advocating all the time.

We were now in the unstable, highly turbulent regime

between (2) and (3). In some ways we were slipping back. After the triumphant euphoria of Apollo 11, it was strange to be on the defensive again.

There was no reason why we should be on the defensive, though many people still asked: Why spend money on Space?

One had to admit this was a reasonable question. But some of the answers that had been given about space spin-off or fall-out — one caustic critic had said 'drip-out' — had been trivial and uninspiring like the example of the Teflon non-stick frying pan which, anyhow, had emerged from atomic energy research 20 years earlier.

There were far better answers near at hand. They ranged from the growing impact of Earth satellites for navigation, meteorology, communications, education and Earth-resources survey. Clarke gave the example of oceanological research ships which obtained their fix from navsats and could return to a precise location to resume drilling operations. He also spoke of the coming importance of satellites for air traffic control.

Metsats have provided the first global view of weather. Good weather survey was important to us but its value was very much greater in other countries. The Indian farmer, for example, depended on knowledge of the monsoon. If monsoons could be accurately predicted it could mean a saving of over 1,000 million Dollars a year; and in these regions a poor crop was not just money; it could mean the difference between life and death.

The cyclone in East Pakistan took over half a million lives. The storm centre had been tracked by satellite but communications were inadequate. People could have got to higher ground or clung to trees had they known. Transistor radios saved scores of lives.

It could be said that the Apollo programme had saved the human race by providing the first view of our Earth in space. These remarkable pictures may have sparked off ecological concern for 'spaceship Earth'. Now it is becoming recognised that Space is the only way to monitor global pollution.

Not only could satellites spot pollution in the land, air and sea — including oil slicks — but their observations could help to maintain and improve fertility and pin-point plant disease.

But space had a huge part to play in expanding communications. Mr. Clarke mentioned that *Wireless World* had recently reprinted his original proposal for 24-hr. communications satellites first published in 1946. The first satellite employing these principles on a commercial scale was Early Bird which had 240 channels. Intelsat IV launched this year has 9,000 channels.

It was not just developed nations that would benefit. Already the satellite network was expanding into poorer regions and soon the first experiments in bringing education, information and entertainment to developing countries would begin.

In India it was planned to link a number of remote villages by direct broadcast TV from the geostationary satellite ATS-F. Mr. Clarke thought this process, as it developed, would stop the rush to the cities and help to maintain the economy of outlying districts in developing countries. People would no longer be isolated by accident of geography.

No intelligent person would dispute these points when they were explained. They were, after all, highly cost-effective.

There were also practical arguments in favour of manned spaceflight. Millions of dollars of junk in orbit could be put right by a man with a screwdriver. Civilisation would depend

on satellites of increasing complexity. Imagine a telephone exchange which could never be serviced!

In the field of space exploration some people had become very emotional or made ridiculous, exaggerated, statements about the superiority of machines over men. In fact, there was no real conflict.

Much of the criticism of space expenditure, Mr. Clarke continued, was purely an expression of dissatisfaction with contemporary society. He called it 'displacement activity' — like a frustrated child kicking the table.

This is particularly true in the US. Politicians, administrators, government officials are too lazy, too stupid — and often too corrupt — to deal with the abuses of society as they should and *could* be. They are absolutely delighted to have the space programme as a scapegoat. They can say: 'We could do all the things you ask, but we haven't got the money — it's all going into space.'

When I was covering the Apollo 15 mission with Walter Cronkite and Wally Schirra on American TV, Wally got into trouble with some viewers by pointing out that the total budget on social services was 30 or 40 times that spent on space. So if you cancelled *all* space expenditure you would only increase social spending 2 or 3%. And although, of course, these figures don't apply to this country, the argument and the attitude they represent are also prevalent here.

Mixed up with this criticism, too, is the current noisy attack on technology in all its forms — in fact, upon reason itself, as exemplified by the interest in drugs; astrology, witchcraft, crazy religions, magic..... Because this sort of thing gets a lot of exaggerated publicity, it may not be as widespread or serious as it sometimes appears. But it is serious enough, and we've just got to ride it out. Fortunately, it's largely self-liquidating; the sort of people who get too deeply involved won't survive.

But then, nor will any of us, unless we use these new tools of space — and use them intelligently. At the same time, we should not let ourselves be so overwhelmed with current crises that we abandon all thoughts of long range goals. Former NASA Administrator Tom Paine put it very well when he said that we shouldn't concentrate on the sewers so completely that we forget the stars.

Almost exactly 25 years ago, I gave this Society — and some of you tonight! — a paper called *THE CHALLENGE OF THE SPACESHIP*. I'd like to end by re-reading some of the words I spoke then:

'I am not unmindful of the fact that 50 years from now (i.e. 25 years from '71, since we're exactly half way there) instead of preparing for the conquest of the outer planets, our grandchildren may be dispossessed savages clinging to the fertile oases in a radioactive wilderness. Yet we must keep the problems of today in their true proportions. They are of vital — indeed supreme — importance, since they can destroy our civilisation and slay the future before its birth. But if we survive them, they will pass into history and the time will come when they will be as little remembered as the causes of the Punic Wars. The crossing of space may do much to turn men's minds outwards and away from their present tribal squabbles. In this sense the rocket, far from being one of the destroyers of civilisation, may provide the safety valve that is needed to preserve it.'

BOOK REVIEWS

Edited by L. J. Carter, FBIS

Most of the books reviewed can be borrowed by B.I.S. members resident in the U.K. Loan requests must be sent by post to the Executive Secretary of the Society, 12 Bessborough Gardens, London, SW1V 2JJ, enclosing 24p. (minimum postage rate).

Some books may not be available for loan. This applies particularly, to reviews of foreign books submitted by overseas members where copies are not held by the Society. The Society can also provide assistance to members who wish to purchase copies of books reviewed.

Encyclopedia of Astronomy

By G. E. Satterthwaite, Hamlyn 1970. 537 pp. £6.30

This book would have been more aptly titled as an *Encyclopedia of Optical Astronomy*, as any Radio Astronomer would be disappointed at the coverage given to his branch. It gives a strong impression that it has been written for the amateur astronomer, with descriptions of how best to observe celestial objects obviously slanted that way. This makes it rather puzzling, therefore, why the maps of the Moon and Mars should be so poor; the Moon especially could do with a larger diagrammatic representation, and a picture of the reverse side somewhat newer than the Lunik 3 one given.

The contents seem to lean too heavily on biography, though Asimov has done this more comprehensively already and the author's choice of relative importance seems questionable, e.g. Airy has 2 pages devoted to him while Einstein and Kepler rate a half-page each. Greenwich and Herstmonceux are well served, perhaps too well, to the detriment of other subjects. In a list of the observatories which the author describes, only 2 are for Radio Astronomy, while Lord's Bridge at Cambridge is mentioned only in passing under 'Pulsars' and 'Cambridge Catalogues of Radio Sources'. The whole approach seems to be a few years out of date, e.g. pulsars, discovered more than 2 years before the book was published, get only a short mention despite their obvious importance, the phenomenon of a comet's tail pointing away from the Sun is put down to light pressure rather than the now-accepted solar wind explanation. Some of the details on Mars and Venus were out of date 2 years before the book was published.

It is, on the whole well-written and very readable. Although an encyclopedia, many parts can be browsed through like a normal book, though definitions tend to be sloppy – perhaps the result of trying to oversimplify for the intended readership of secondary school/1st year university/educated layman. The optical side, though comprehensive, is insufficiently researched. In such cases as the explanation of Interference it is, perhaps, impossible to resolve the difficulty of how much to give. While the explanation given may satisfy the intended readers, it is basically misleading and does not stand further investigation. Perhaps more space should be given to the basic definitions and less to repetitive exercises such as repeating 'Ares was the Greek God of War' under headings of 'Areology' and the succeeding 'Ares', or defining apogee, apojove and aposaturnium in order when one definition would do.

For the amateur astronomer, certainly, the information is there. The trouble with this, as with all encyclopedias, is that one tends to have to chase from definition to definition. All too often I found the chain broken when a heading was

missing. (e.g. in INTERFERENCE in thick type, denoting a paragraph of its own, is MOIRE FRINGES, which heading does not exist. Similarly with at least one other, and there is a circular route while looking for elucidation on Radio Interferometers. INTERFEROMETER sends you to RADIO INTERFEROMETER which tells you it works on the same principle as the optical method. It also refers you to RADIO ASTRONOMY, which does not mention Radio Interferometers).

Mr. Satterthwaite's love of the actual observation part of optical astronomy is shown in the excellent guides to lunar and Martian surface features and the detailed descriptions of celestial objects.

It is a pity that little notice has been taken of the results of astronautics, even of the plans for orbiting astronomical telescopes. The book was published in 1970, i.e. 2 years after Venera 4 and Mariner 2 had shown the Venus surface temperature to be very high, yet in one place the book gives the older view that the surface could be as cool as Earth's, (and no other). Mariners 6 and 7 in August 1969 are tabulated, so the Venera shots (even 5 and 6) were not too late to have their results included, but they are not even mentioned. The Mariner Mars missions are mentioned and 2 photographs reproduced from Mariner IV, yet the camera evidence it sent back is barely touched upon except for one small reference to the 'ring structures' seen, and the old figure of N₂ 94% content of the atmosphere given (with 85 mb pressure). Mariner showed the main constituent to be CO₂, and the pressure to be 5 mb. The latter had, anyway, been doubted long before Mariner, with a 25 mb spectroscopic determination, 10 from i.r., and an Aerobee shot giving 5-20 mb. The photos of the Moon draw more on astronautics, though I doubt if many in that branch of science would agree that the Apollo and Orbiter pictures show that the craters are of volcanic origin. At one point, too, Mr. Satterthwaite tut-tuts over the 'undignified and acrimonious' argument over whether Adams or Le Verrier predicted Neptune's position first, while not too far from that making some rather bitter remarks about lunar 'impact' theorists!

On the whole, it is a good book, and relatively simple for optical astronomers and others interested in the heavens, but it would have been better if some of its facts were brought up to date. Its price would seem rather restrictive, though the amount of information given is tremendous.

The Atlas of the Universe

By Patrick Moore, Mitchell Beazley Ltd., with George Philip and Son, 1970, 272 pp. £10.75

This is a magnificent book, a spectacular, almost an astronomical extravaganza. It has been beautifully compiled, with taste and imagination, and its presentation is captivating and exciting from cover to cover. The producers have had the pick of the finest astronomical photographs ever taken and, it would seem, of the most gifted illustrators, for the copious diagrams are illuminating, ingenious and generally pleasing into the bargain.

The forward by Sir Bernard Lovell commends the Atlas of the Universe to young and old, as a guide to the Universe as we understand it today. He continues 'As men probe deeper and deeper into the secrets of the Universe in coming years, the Atlas will retain its value as a guide to the new

discoveries'. In fact, it puts the Universe into perspective, giving a clear understanding and a firm foundation from which to advance.

The Atlas embraces 5 sections starting, by way of introduction, with 'The Observation and Exploration of Space,' which deals with the tools, methods, ideas and future possibilities of Astronomical and Space Research in its widest sense. Sections follow on The Earth from Space, the Moon, the Solar System and the Stars and Galaxies, mapping for us the outer limits of man's probing to date. In each section the scene is set by a brief historical survey giving early ideas, followed by a superbly illustrated account of the present state of our knowledge.

The text, whilst entirely adequate, serves mainly as a thread, linking together and supporting the profusion of photographs, diagrams and maps which, with their excellent captions, largely tell the story unaided, for it is a story that really comes to life in the glorious coloured pages of this Atlas.

Looking at 'The Earth from Space' we find described the techniques for mapping, studying the atmosphere, the weather, geology, vegetation, even charting the distribution of people and of fishes! With the Moon, Patrick Moore surely has no equal, and the maps and photographs here are outstanding. Next the Sun and the planets are each treated in turn; all are superb and again, comprehensive facts, statistics and views are provided. The section on Mars, in particular, struck the reviewer as being exceptional, containing not only the Mariner Mosaics but a remarkable series of telescopic views of the surface features and even a Radar profile of the contours.

Finally the Stars and Planets, the whole Universe, in fact, apart from our tiny colony, is treated with equal thoroughness and clarity, whether describing the work of the Astrophysicist, the rival evolutionary theories, or just catering for the needs of the simple star-gazer. The maps in this section are excellent and all the principal objects to delight the observer are highlighted. Perhaps, if one may be allowed one small disappointment, it would be that scant reference is made to the study of Pulsars, surely the most challenging of the recent discoveries.

In his Epilogue Dr. Thomas Paine, NASA's Administrator, is certain that before the end of the century the first pioneers will be exploring Mars. The possibility cannot be denied. Certainly the impression given by this stimulating book is that of 'Reaching for the Stars'.

100,000 copies have been produced, in 7 different languages. They will be good value for money in any currency.

A.E. FANNING.

Organizing Space Activities for World Needs

Ed. E.A. Steinhoff, Pergamon Press, 1971, 490 pp. £10.

In 1968 the 19th Astronautical Congress chose as a series of sessions 'Organising Space Activities for World Needs', the proceedings of which are recorded in this volume. The book covers the many and diversified scientific, technical, legal and managerial facets of an international space programme. Although upon first glancing through the book it appeared to be a typical philosophical approach to the future developments of space science, closer examination revealed a thorough treatment of the technological and

organisation requirements of each topic.

However there are chapters which seem to be out of place in a work of this general nature, e.g. a chapter devoted to a 13W travelling -wave tube and 2 chapters not even in English.

I preferred the sessions dealing with systems and technology although, paradoxically, these contained the anomalies previously discussed. One chapter I particularly liked was concerned with technological requirements of remote sensing satellites. This was well laid out with a clear step by step argument of the many requirements, from the types of on-board equipment to the lubricating of the camera shutters. Unfortunately some other chapters did not successfully follow this technique.

The book is a worthwhile addition to anyone who wishes to see space science in its perspective and gain an insight into the requirements of international cooperation.

T.J. BERESFORD.

Of a Fire on the Moon

By N. Mailer, Little, Brown & Co. 1970, 472 pp. Dolls.7.95.

Fire is a non-fictional account of the Apollo 11 lunar landing mission by an American novelist. The title refers to the kindling of a rocket flame on the airless Moon by the lunar module's ascent stage.

The story of Apollo 11 has been told by reporters more objective than Mailer. He is distracted from the matter at hand by narcissism and possessed with social, ethnic, and political theories which frequently intrude. However, he is an accomplished writer, and such diversions only serve to infuse the account with vitality. Imagine Charles Dickens covering a Moon launch and you have a fair feeling for *Fire*.

The book is divided into 3 parts. In part 1 the Apollo 11 mission is treated from the viewpoint of the bystander, particularly the working press. Mailer provides fascinating insights into the personalities of the astronauts and high NASA officials as revealed at press conferences and receptions given at Houston and Cape Kennedy. His accounts bear little resemblance to standard newspaper coverage of such events, and this offset yields a parallax which enables us to calculate the size of the public figures involved.

Less prominent NASA personnel, chiefly engineers and technicians, pose a problem for Mailer; he finds it difficult to reconcile the romantic purpose of their work, landing men on the Moon, with what he feels is their mundane style of life. He has something of the same problem with the astronauts themselves but eventually manages to certify them as workaday heroes. The wellknown science fiction writer Ray Bradbury harboured similar feelings toward space professionals, speaking of 'clean young rocket men with their antiseptic bloomers and fishbowl helmets.'

Part 2 surveys the same period of time and the same sequence of events, but the viewpoint shifts from the observer to the participant - Apollo 11 is described as it is experienced by the astronauts. Again we are treated to choice character analysis, although now subordinated to technical exposition; after the rather free-wheeling first part the author has disciplined himself to recite the operational, engineering, and scientific guts of a Moon

flight. The presentation is directed towards a lay audience, but it would be a rare reader, however well informed, who did not acquire new information.

Part 3, which is disjointed and weak, is mercifully short. The author seems to have added it simply from a desire to write a work of 3 parts.

Fire supplies more detail than the casually interested reader may care to digest, and it strays too far from the path of orthodox science writing to have received much notice in astronomical circles. Thus, the book lacks a natural audience. This is unfortunate since it contains much of value.

W.I. McLAUGHLIN.

Astronautical Multilingual Dictionary

By Elsevier Publishing Co., 936 pp. 1970.

This Dictionary, prepared in association with the International Academy of Astronautics and the International Institute of Space Law, appears as the copyright of the Czechoslovak Academy of Sciences.

Seven languages are covered, viz., English, French, German, Russian, Italian, Spanish and Czech and, like most multi-language dictionaries, it is cross-referenced to provide access to information regardless of what language one starts with.

It is a large, well-produced volume, and the amount of work which has gone into its compilation must be tremendous.

However, the claim that it covers 40,000 technical terms is misleading, for a large number of the terms are not technical in the sense of belonging to the sphere of astronautics. Many are purely legal, no doubt in deference to the associated International Institute of Space Law. But an even larger number are everyday words which can be found in ordinary dictionaries, e.g., *discovery, universal, custom, emblem, tide, expense, ignore, North Pole*, etc.

At a rough estimate, these 'ordinary' words constitute at least 20-25% of the total number and make the supposedly specialist dictionary unnecessarily bulky.

On the other hand, special words which have been in use for many years, e.g., the Russian *Illuminator* (for a spacecraft porthole), are not included.

No dictionary is perfect nor up-to-date by the time it is published, but, in this case, the specialist user may find the dictionary to be less useful than some 2-language dictionaries which have already appeared.

MRS.L. PARKS.

The Rush Toward the Stars

by T. Logsdon, Franklin, 1970. 224 pp. Dolls.6.80.

This book contains easy to understand descriptions of very generalised subjects ranging from satellites to life on other planets, and from astrodynamics to bioastronautics. There is no information about individual space missions or reports on particular projects so this is not the book for someone who wants to know who first saw the Moon at close quarters, what was the vaguely familiar name of his spacecraft, or how many thousands of a second his launch was late. Rather this is a collection of explanations of theories, laws and techniques. Every aspect

of spaceflight appears in one chapter or another. Stargazing is traced from Aristotle to Brahe, Kepler and Newton, together with brief explanations of laws they postulated.

'Project Big Shot' presents a detailed account of a balloon project in which the author participated. It shows very effectively the problems faced by small teams of researchers, those posed by the hardware, the weather and the politicians. The more serious subject matter is brightened by examples in a lighter vane e.g., gravity-powered trains travelling through the Earth's crust, and launching craft from self-supporting towers thousands of miles high. A variation of the Pansferinia theory states that life may have arisen from refuse discarded by a visitor to our humble planet in its infancy. Our recent ancestors may well have been apes, but we may, ultimately be descendants of alien microbes on an extragalactic toffee wrapper.

This is a deceptively simple book, possibly because of the lavishly spaced print, typical of American publications, and large uncluttered diagrams. More use could have been made of these diagrams, and mathematical proofs could have been introduced without appreciably complicating matters. However, the author kept his text simple though conveying far from simple ideas e.g., gravity and its implications in spaceflight, detached shock waves and how they are made use of in ablative nose-cones, time dilation, etc. In doing so, he has produced an interesting, amusing and very informative book for newcomers to space science.

The spirit in which it was written can be seen in the last line or two which read, '.....a man clinging to what he has, is no man at all. But a man looking up at the stars, there is a man.'

I. GRAHAM.

Astrodynamics Vol. 1.

By L. S. Herrick, D. Van Nostrand, 1971, 540 pp. Dolls.15.00.

This is a magnificent introductory book, permeated by the personality of the author, which breaks away from the traditional approach to celestial mechanics (*alias* astrodynamics). It is written both for the beginning student, who will benefit from the numerous worked examples and exercises, and for the practising astrodynamist, who will benefit from Professor Herrick's cogent comments.

Professor Herrick was brought up in the old tradition, where a computer was 'one who computes' and not a machine. He makes the point that formulae need adjusting for a particular piece of 'computing equipment', for the degree of accuracy required, for the computational time available, and for the personal satisfaction of the 'computer'. For this reason Herrick, intentionally, does not provide a set of machine programmes, (where flexibility may be limited) but writes numerical examples in such a way as to enable rapid translation into any machine language.

I found the book very satisfying and look forward to the promised second volume.

Prof. J.S. GRIFFITH.

Purchase of Books

The Making of Kubrick's 2001. This can be obtained from New American Library, 1301 Avenue of the Americas, New York, New York 10019, USA. Price \$1.50.

A second opportunity to visit the John F. Kennedy Space Center and witness the launching of Apollo astronauts to the Moon is being arranged by Transolar Travel in conjunction with the British Interplanetary Society. The Apollo 16 party leaves by Caladonian/BUA 707 from Gatwick on 12 March.*

The programme is again based on the Atlantic Beach Lodge, Cocoa Beach, and includes opportunities to visit the Manned Spacecraft Center at Houston and the George C. Marshall Space Flight Center at Huntsville, Alabama.

A BIS Information Centre will be situated at the Motel to ensure that the party is kept fully informed on all developments.

The previous tour arranged at the time of Apollo 15 last July is unlikely to be forgotten by any of the 186 participants. Tour arrangements were personally organised by David McGee, director of Transolar Travel, and the party was also accompanied by Len Carter and Ken Gatland. Opportunity was taken to make many new contacts with NASA and industry of great benefit to the Society and its publications.

Most memorable feature of the 8 hr. outward flight (apart from first-class meals served by the BUA/Caladonian stewards and hostesses) was the stopover in Bermuda when passengers were allowed off the 707 for an hour. Emerging from the air-conditioned cabin was like stepping into a wall of heat and one was glad to reach the sanctuary of the air-conditioned terminal buildings which open directly on to the beach and an azure blue sea.

Back aboard the jet we were soon away for another Atlantic hop which brought us, at around dusk, to Miami Airport. (The Apollo 16 excursion will go to Melbourne Airport, Florida, which is less than one hour travelling time from Cocoa Beach). After clearing Immigration we boarded air-conditioned coaches for a night-ride north through the outskirts of neon-lit Miami as electrical storms played on the horizon. Halfway to our destination we stopped for supper (or was it breakfast?) at a huge all-night restaurant alongside the freeway.

In the early hours of the day following our departure from Gatwick we arrived at Cocoa Beach. Crickets were chirping merrily from newly watered vegetation surrounding the Motel facade as weary travellers, unaccustomed to the heat outside, got the keys to their air-conditioned rooms and fell into bed.

Next morning we were able to see our surroundings more clearly. The Luxury Motel - with its 2 swimming pools - was right on the coast facing the sunlit blue of the Atlantic with an inviting beach of white sand stretching as far as the eye could see.

On the front of the Motel was a bold display: 'Welcome to our English Visitors' (later changed to 'British' as Welsh and Scottish members made themselves known!).

So much activity was packed into those 8 days - including 'off-duty' excursions to the tropical Cyprus Gardens and the preview centre of Disney World - that it is impossible to describe events in detail.

The tour of the Kennedy Space Center, was previewed the previous evening at the Motel by Messrs. Gatland and Carter with the aid of slides. In an adjoining room an Astronauts'

* Members and others wishing to join this 10-day excursion should contact Mr. L. J. Carter, Executive Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

EQUIPMENT APPEAL FUND

With this issue of *Spaceflight* The BIS Council announces the opening of a special Equipment Appeal Fund to support one of the Society's main activities - Publications. A target of £5,000 has been set.

Money raised will purchase equipment which the Society urgently needs for composing, photocopying, photographic, etc. We need this equipment to make the most effective use of our regular income (mainly derived from members' subscriptions) and to prevent subscription rates from escalating with the inflationary spiral. In the last year alone printing costs increased by 25% and postal charges by 50%. Subscription rates have stayed the same. Members should therefore be concerned that the Fund is well supported and that the target is quickly reached.

reception was just finishing, and during the B.I.S. presentation one of the Motel staff interrupted urgently to say there was a piece of moonrock in the next room under armed guard and would we like to see it before it was taken away. Never before did a captive audience disappear so rapidly!

Approaching the Kennedy Space Center from Merritt Island over one of the causeways spanning the Banana River one could identify across the water the shape of the Vehicle Assembly Building separated by some 3 miles from a structure which we knew was the Saturn V/Apollo 15 vehicle cradled by its servicing tower.

During the NASA-organised coach tour of the Space Center we were eventually taken to an observation point only a quarter of a mile from Launch Complex 39A where the huge rocket was being prepared. It was just 2 days from the time when it would blast off for the Moon.

The party was also taken into the cathedral-like interior of the VAB. Visits were also made to various launch sites along the coast including Launch Complex 34 where NASA launched the first Apollo spacecraft into Earth-orbit by Saturn IB.

Some time was also spent inspecting the Space Museum which contained examples of most American missiles and space vehicles. Nearby was an impressive gift hall, where souvenirs of the space effort could be purchased, and also a cinema showing Apollo films in colour.

On launch date (22 July) the Motel began serving breakfast at 4 a.m. so that we could reach the Space Center in good time to avoid the crush. Alongside the approach roads people were camping out in tents and trailers.

The 35-minute drive began in darkness but as we made our way once more across the causeway dawn was breaking. In the distance the VAB and Apollo 15 could be seen illuminated by floodlights. Within minutes, like a backcloth to the drama, small puffy clouds near the horizon split the first rays of the Sun into huge fingers of pink and orange light stabbing the darkness.

As we took our seats on the viewing stand alongside the Launch Control Center, the sky had brightened into glorious day. Electrical storms that had plagued the launch crews during previous weeks had disappeared. We watched astronauts Scott, Irwin and Worden and NASA officials being driven in a procession of vehicles to the launch pad. It was about T minus 3½ hours.

[to be continued]

A Selected Reading List

MAN IN SPACE

This is the first part of a reading list which deals with the problems of manned space programmes, particularly as relating to the Apollo flights.

Many of the items listed are available on loan through the Society, requests should be sent to the Executive Secretary enclosing 30p (minimum postage rate) for *each* book or report desired. Items are forwarded only on the understanding that the maximum loan period of one month will not be exceeded. This must be strictly adhered to, to avoid inconvenience to other borrowers.

Popular Works

PRE-APOLLO

<i>Author</i>	<i>Title</i>	<i>Year of Publication</i>
Abbas, K. A.	Till we reach the Stars (The story of Yuri Gagarin)	1961
Cooper, L. G.	The Astronauts – Pioneers in Space	1961
Gagarin, Y.	Road to Stars	1962
Gatland, K.	Manned Spacecraft	1967
Grissom, V.	Gemini: A Personal Account of Man's Venture into Space	1968
Sobel, L. (Ed.)	Space: From Sputnik to Gemini	1965
Stoiko, M.	Project Gemini	1963
—	The Dawn of the Space Age (Russian reprints of newspaper articles, conferences etc.)	1961
SP-12	3rd United States Manned Orbital Space Flight	1962
SP-45	Mercury Project Summary (4th manned orbital flight)	1963
SP-121	Gemini Midprogram Conference	1966
SP-129	Earth Photographs from Gemini III, IV and V	1967
SP-138	Gemini Summary Conference	1967
SP-171	Earth Photographs from Gemini VI through XII	1968
CR-1106	Project Gemini: A Technical Summary	1968
SP-4001	Project Mercury – A Chronology	1963
SP-4002	Project Gemini – A Chronology	1969
SP-4201	This New Ocean – A History of Project Mercury	1966

APOLLO

T. Alexander	Project Apollo	1964
Armstrong, N., Collins, M. and Aldrin, E.	First on the Moon	1970
Bates, S. and Messel, H. (Ed.)	Man in Inner and Outer Space	1969
Booker, P., Frewer, G. and Pardoe, G.	Project Apollo – The Way to the Moon	1969
Burgess, E.	Assault on the Moon	1966
Coombs, C.	Project Apollo: Mission to the Moon	1966
Fairley, P.	Man on the Moon	1969
Knight, D. (Ed.)	American Astronauts and Spacecraft: A Pictorial History from Project Mercury through Apollo 13	1970
O'Leary, B.	The Making of an Ex-Astronaut	1971
Young, H., Silcock, B. and Dunn, P.	Journey to Tranquility: The History of Man's Assault on the Moon	1969
SP-201	Apollo 8 Photography Analysis	1969
SP-214	Apollo 11: Preliminary Science Report;	1969
SP-235	Apollo 12: Preliminary Science Report	1970
SP-238	Apollo 11: Mission Report	1971
SP-272	Apollo 14: Preliminary Science Report	1971
SP-4009	The Apollo Spacecraft – A Chronology	1969
SP-6001	Apollo Terminology	1963

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: telephone 01-828 9371.

FILM SHOW

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1, on **12 January 1972**, 6.30–8.30 p.m.

The Programme will include the following:

- (a) Man in Space – the Second Decade.
- (b) Anatomy of Success (Intelsat).
- (c) Apollo 15 – The Mountains of the Moon
- (d) The Knowledge Bank.

No admission tickets are needed. Members may introduce guests.

SPACE STUDY MEETING

The 10th Space Study Meeting will be held in the Kent Room, Caxton Hall, Caxton Street, S.W.1, on **10 February 1972** from 6.30–8.30 p.m.

The programme will be as follows:

- (a) Highlights of the Apollo 15 Cape Kennedy Visit by M. F. Allward.
- (b) Arrangements for an Apollo 16 excursion

APOLLO 16 LIFT-OFF, 12-21 March 1972

The Society, in association with Transolar Travel Ltd., is arranging a Special Charter Flight for Members and Guests to see the Apollo 16 lift-off.

A special excursion will be made by a Boeing 707, leaving Gatwick Airport for a direct flight to Melbourne, Florida, with coaches meeting the flight to complete the short journey to Cocoa Beach.

Accommodation will be provided at a Luxury Motel for eight nights.

A comprehensive coach tour of the Space Facility will be made, including a visit to the Vertical Assembly Building and Launch Complex 39.

The total cost of flight and accommodation, excluding meals, is £128.

Further information and booking forms are available from The Executive Secretariat, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

FILM SHOW

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1 on **5 April 1972**, 6.30–8.30 p.m.

The Programme will provide a second opportunity to see a number of outstanding films, i.e.:

- (a) Spaceport, U.S.A.
- (b) Returns from Space.
- (c) The Moon – Old and New.
- (d) Apollo 15: The Mountains of the Moon.

No admission tickets needed. Members may introduce guests.

MAIN MEETING

Theme **Rocket Propulsion and Space Transportation**

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1 on **18-19 April 1972**.

Subject areas are as follows:

- (a) Ground Test Facilities
- (b) High Energy Propulsion
- (c) Solid Propellants
- (d) Thrust Vector Control
- (e) Rocket Plumes (Flame Physics)
- (f) Instrumentation Techniques
- (g) Advanced Propulsion.
- (h) Space Shuttle Technology, which will also include

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12 Bessborough Gardens, London, SW1V 2JJ

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

All material is protected by copyright. Responsibility for security clearance, where appropriate, rests with the author.

Associated Systems. Subject areas are as follows:

- | | |
|--------------------------|--------------------------|
| (a) Re-entry | (g) Space Stations |
| (b) Lifting Body | (h) Structures |
| Aerodynamics | (i) Propulsion |
| (c) Heat Transfer | (j) Guidance and Control |
| (d) Refractory Materials | (k) Mission Analysis |
| (e) Design Studies | (l) Cost Effectiveness |
| (f) Space Tug | |

Offers of papers are invited.

Further details are available from the Executive Secretary.

27th ANNUAL GENERAL MEETING

The 27th Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on **14 June 1972** at 6.30 p.m.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed, signed and returned not later than 3 June 1972.

If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members before the date of the meeting.

12th EUROPEAN SPACE SYMPOSIUM

To be held at a venue in Northern Italy over a 3-day period in **mid-June, 1972**

Theme **Control and Guidance of Space Vehicles**

Members interested in participating and for presenting papers are invited to communicate with the Executive Secretary.

MAIN MEETING

Theme **Communications Satellites**

To be held at the University of Southampton on **19-20 September 1972**.

Subject areas are as follows:

- (a) Regional Satellites
- (b) Aeronautical and Maritime Satellites
- (c) Review of Present Systems
- (d) Transmission of Digital Data
- (e) Information Storage and Retrieval
- (f) Operations Experience
- (g) Educational (TV) Satellites.
- (h) Power Supplies.
- (i) Ground Stations.

Offers of papers are invited.

Further details are available from the Executive Secretary.

APOLLO 17 LIFT-OFF DECEMBER 1972

The Society, in association with Transolar Travel Ltd, is arranging for members and guests to witness the Apollo 17 lift-off. This will be the last of the American manned missions to the Moon, using the giant Saturn V rocket. It will be an historic moment.

Those interested are invited to make *early* reservations. Reservation forms and other details can be obtained on request.

ADVANCE NOTICE OF FUTURE MAIN MEETINGS

Offers of papers for presentation at the following Main Meetings of the Society, now being organised, will be welcomed.

Further details are available from the Executive Secretary on request.

- (a) Structure of Space Vehicles and Spacecraft.
- (b) Sounding Rockets and Experimental Results – 3.
- (c) Earth Observation Satellites.
- (d) Management of Space Projects.

SPACEFLIGHT

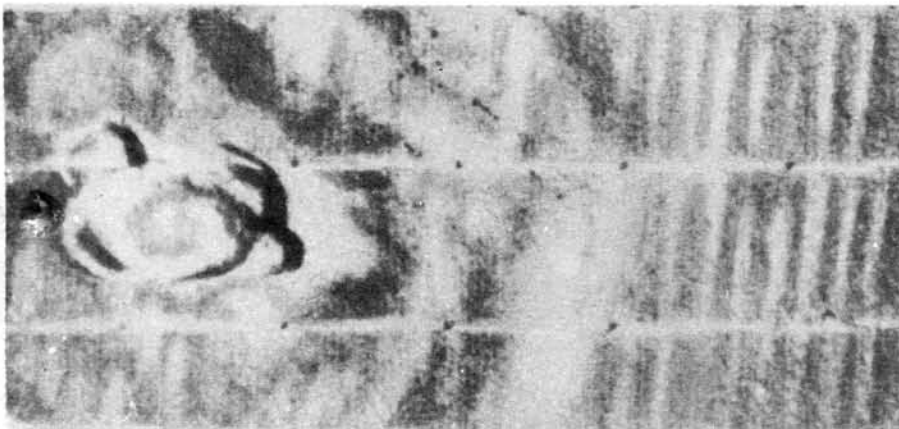
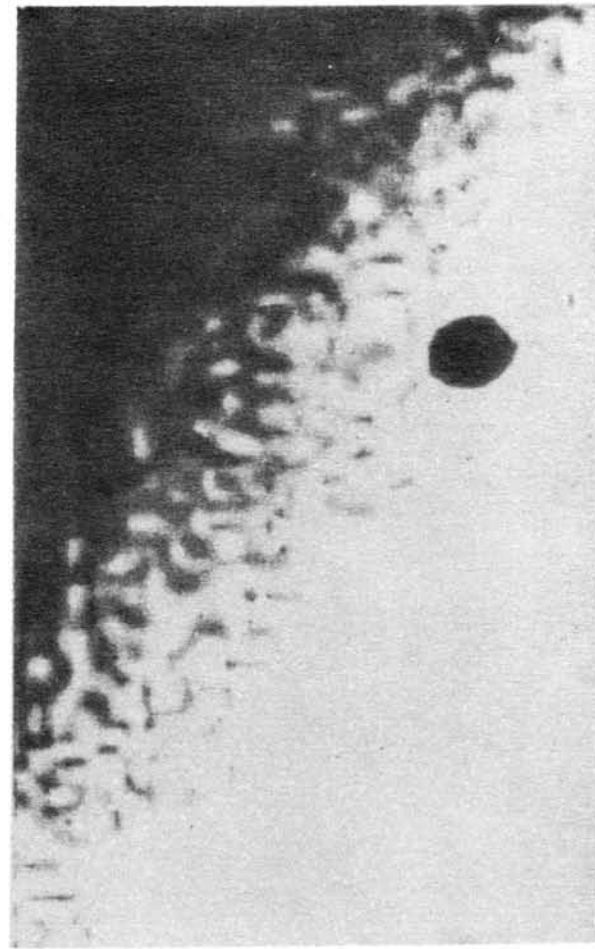
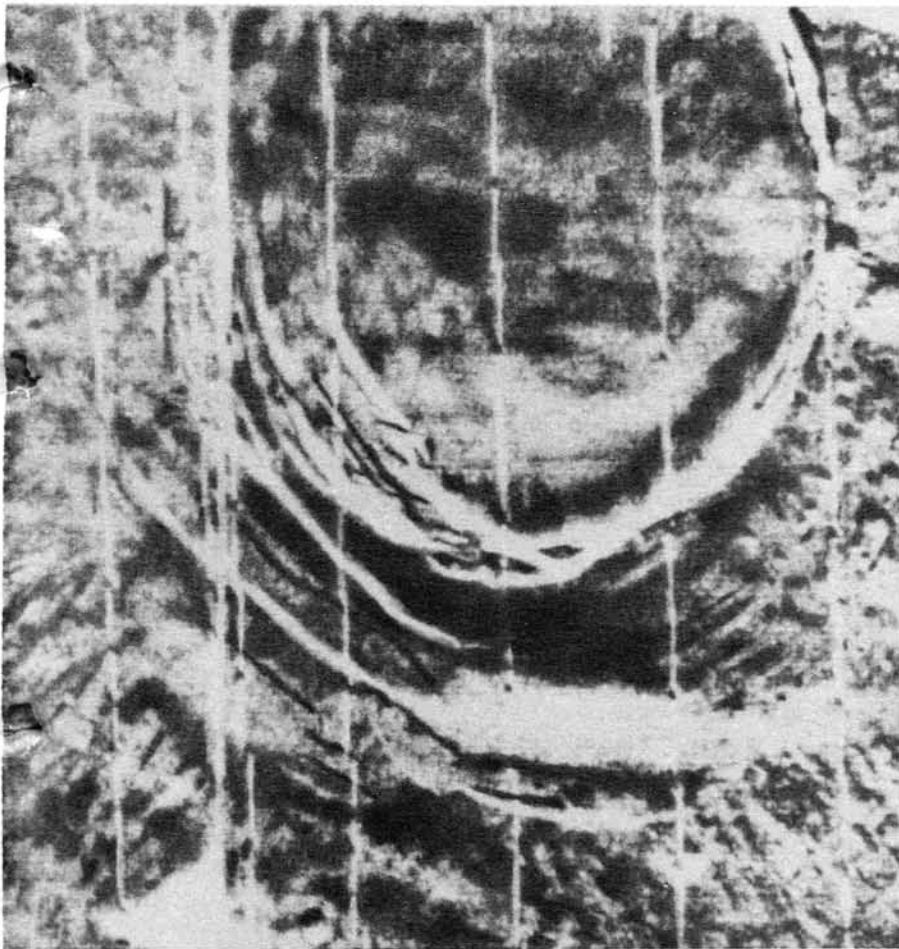
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КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-2

(спейсфлайт)

По подписке 1972 г.

Volume 14 No 2 February 1972



Published by The British Interplanetary Society

1972 SUBSCRIPTIONS

Members are reminded that the 1972 subscriptions will fall due for renewal on 1st January, the rates being as follows:

	<i>Sterling</i>	<i>US Dollars</i>
Student Members	£3.50	\$10.00
Members	£4.50	\$12.50
Senior Members	£5.00	\$14.00
Associate Members	£5.50	\$15.50
Fellows	£6.00	\$17.00

The above fees include the receipt of *one* of the Society's publications, ie the *Journal* or *Spaceflight*. A further £3.50 (\$10.00) should be added where members wish to receive *both* publications.

The US dollar rates are slightly higher this year to equal sterling equivalents, owing to a change in value of the dollar and the increased banking costs payable on conversion into sterling.

Students *over* 21, but still receiving full-time education and who wish to claim the reduced fee must submit a Certificate from their Education Authority **when remitting**.

Remittances should be sent to the Executive Secretary, The British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

PAYMENT BY BANKER'S ORDER

Over 1,000 members of the Society in the UK remit their subscriptions by annual cheque. If the majority of these paid by Bankers Order, the saving in the Society's work-load and costs would be enormous, and the convenience to Members would also be very great.

Bankers Orders make it unnecessary to send out subscription reminders, sometimes frequently, for the high cost of reminders, when set off against late subscription renewal, reduces considerably the useful sum available for Society activities. This shows how much it lies in the interest of every member to pay his subscription by January 1st each year.

At a time of rapidly rising costs, we must do everything possible to improve our income and delete every unnecessary expense.

We appeal to you to consider this means of payment for the future. Order forms are attached to the annual subscription notice each year; blank forms, to operate from 1972, are available on request.

Please write or telephone for one now.

British Interplanetary Society
12 Bessborough Gardens, London SW1V 2JJ
Tel. 01-828 9371

EQUIPMENT APPEAL FUND

We should like to thank those members who have already responded to the President's letter appealing for funds to help the Society purchase composing and printing equipment.

A target of £5,000 has been set. By 31st December, 1971 donations totalled £540.

Each member should be concerned to see that we reach our target, and help to contain the level of ever rising costs.

If you have not already done so, will you please contribute now, and generously. Your donation is badly needed and will be most welcome.

Please address your gift to:

**The Executive Secretary,
British Interplanetary Society,
12 Bessborough Gardens,
London, SW1V 2JJ.**

APOLLO 16 MARCH, 1972

Travel to Cape Kennedy by Boeing 707 for 10 days (8 nights) at a Luxury Oceanside Motel during the lift-off date of Apollo 16.

Inclusive cost .. £128.00

Including Tour of Kennedy Space Centre

This excursion departs from Gatwick on 12th March, 1972 and will be accompanied by Kenneth W. Gatland, F.R.A.S., F.B.I.S. and

L. J. Carter, A.C.I.S., F.B.I.S.

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COVER

VISTAS OF MARS. Mariner 9, which became the first artificial satellite of Mars on 14 November, has been sending a vast number of remarkable pictures of the Red Planet and its moons. *Top left* shows a huge crater, 110 km across, near *Nodus Gordii* (Gordian Knot) photographed on 28 November. Scientists at the Jet Propulsion Laboratory say the feature and its immediate surroundings 'are high ground, emerging island-like from a sea of wind-blown dust'. They add, 'the multiple concentric fractures on the western rim and the abundant rimless craterlets suggest this is a caldera or volcanic collapse crater, one equal in size to the largest on the Earth or on the Moon'. *Right*, Phobos, the larger of the 2 Martian moons 16 by 22 km across, appears as a dark spot against the planet's surface. The computer-enhanced picture was taken from a distance of about 150 000 km a few hours before the spacecraft went into orbit. *Below*, this oblique view of a crater complex near *Ascraeus Lacus* in the Tharsis region of Mars was taken by Mariner 9 during its 30th revolution. The main crater is about 21 km across.

United States Information Service

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 14 NO 2 FEBRUARY 1972

MILESTONES

November

- 14 Mariner 9 becomes first artificial satellite of Mars after 15-min. braking burn completed 00.33 hrs. GMT. First pictures by TV show little surface detail because of extensive dust storms.
- 16 NASA sends Telex message to Moscow informing USSR Academy of Sciences that analysis of Mariner 9 trajectory 'shows that ephemeris used in planning the orbit must be adjusted by 60 km'.
- 23 NASA announces contract negotiations with TRW Systems Group for two automated High Energy Astronomy Observatories (HEAO) to be launched by Titan III from Cape Kennedy in 1975-77. HEAO – to study high energy radiation from space – will be 11.5 metres long by 3 metres diameter, total weight 9700 kg including some 5600 kg of equipment. Orbit-adjust stage – developed by Lockheed Missiles and Space Company – will circularise initial elliptical parking orbit at 370 km.
- 24 Soviets launch 'new-generation' communications satellite Molniya 2 'for ensuring the functioning of the remote telephone-telegraph radio-communications systems in the USSR, for relaying central TV programmes to stations in the Orbita network, and for international co-operation'. Initial orbit ranges between 460 and 39,350 km inclined at 65.4 deg. to equator.
- 24 *Novosti* reports that French Stereo experiment aboard Mars 3 continues to function.
- 25 All-party Parliamentary Select Committee on Science and Technology in 345-page Report recommends establishment of 'single independent space agency to be responsible to the Minister of Aerospace for all the United Kingdom's civil interests in space'; also vigorous participation in U.S. post-Apollo programme.
- 26 Mariner 9 photographs Deimos, outer moon of Mars, from distance of about 8530 km. Pictures show small irregular body with a 'lumpy, oval-shaped object' which may be hill or crater.
- 27 Braking burn applied to Mars 2 at 23.19 hrs (Moscow time) to put spacecraft into Mars orbit ranging between 1380 and 25000 km from surface, inclined at 48° 54' to equator; period 18 hrs. Mid-course corrections were made on 17 June and 20 November in conjunction with Crimea deep space tracking station; third correction and braking manoeuvre of 27 November carried out automatically by on-board computer after separation of a capsule 'which delivered to the surface of Mars a pennant with the USSR coat-of-arms'
- 28 Mars 3 at 09.00 hrs. (Moscow time) is 138.3 million km from Earth having covered distance of about 472 million km.
- 30 Mariner 9, in photographs obtained from distance of about 5530 km, defines Phobos, inner moon of Mars, as irregular pock-marked body with at least one large crater.

[Continued on page 80]

AFTER PROSPERO

By Kenneth W. Gatland

What follows Britain's success in launching the Prospero satellite by Black Arrow on 28 Oct. 1971? Considering that this country had all the technology in Blue Streak and Black Knight 10 years ago to undertake a major satellite programme, it is somewhat depressing to record that political apathy and miscalculation of the importance Space would play in our lives resulted in Britain becoming only the *sixth* nation to achieve orbit by independent effort — after the Soviet Union, the United States, France, Japan and China (Table 1)!

Before success was finally achieved with Black Arrow R.3, on a shoe-string budget, the Government had taken a decision to cancel the launcher on the grounds that further satellites could be launched more cheaply in the United States, and also that Black Arrow was too small to meet future requirements.

The latter point is something this Society has consistently argued since the project was set up by a previous Conservative Administration in 1964. Whether or not it is wise to lose all control over launching one's own satellites is another question. It is ironical that had it not been for the continuing dependance by ELDO on Blue Streak within the Europa 2 programme, all significant rocket engineering in this country would now already have come to an end.

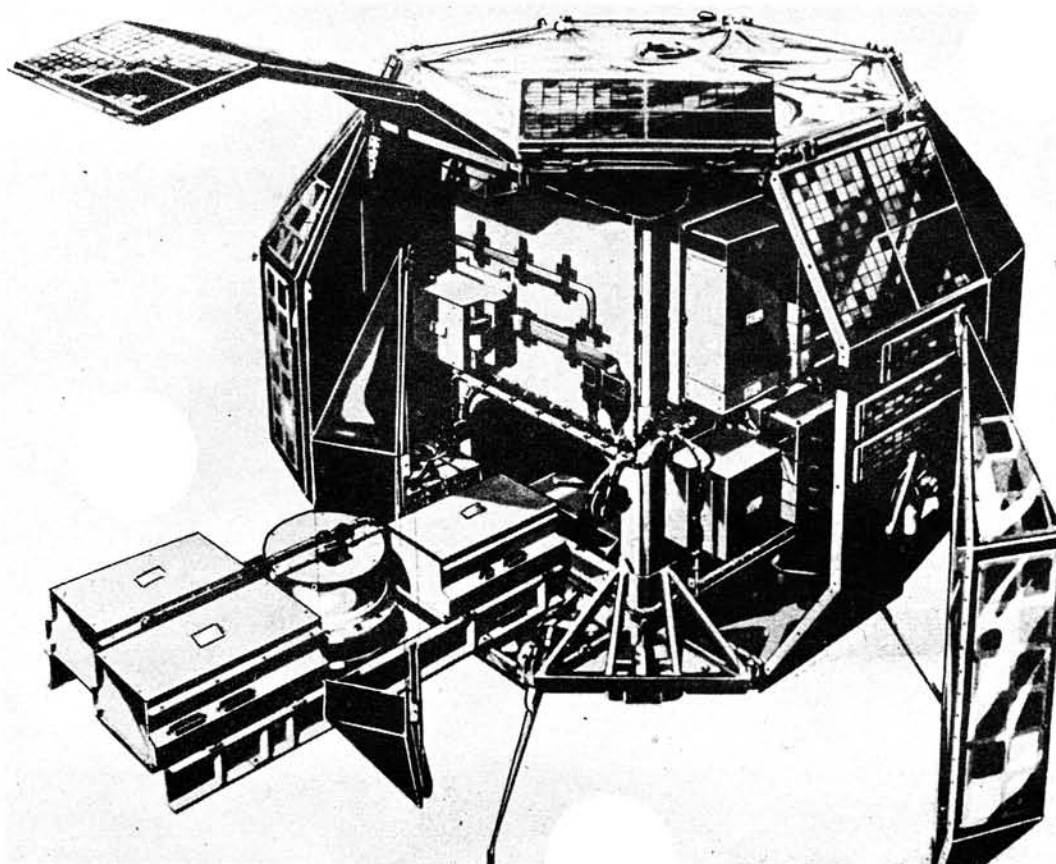
The decision of the previous Labour Government to end further financial contributions to Europa development has meant the British aerospace industry — notably Hawker Siddeley Dynamics and Rolls-Royce — being eliminated from all contracts associated with the 3rd-generation launcher Europa 3.

Table 1. First National Satellites Launched by Independent Effort.

Country	Date	Satellite	Satellite Mass (kg)	Launch vehicle
USSR	4 Oct 1957	Sputnik 1	83.6	Modified ICBM
USA	1 Feb 1958	Explorer 1	13.97* (4.8 payload)	Juno I
France	26 Nov 1965	Asterix 1	40	Diamant A
Japan	11 Feb 1970	Ohsumi 1	38* (12 payload)	Lambda-4S
China	24 Apr 1970	China 1	173	Modified IRBM (?)
UK	28 Oct 1971	Prospero 1	65.8	Black Arrow

* Includes final stage of launch vehicle.

What happens now? Mr. A. V. Cleaver, Divisional Director and General Manager (Rockets) of Rolls-Royce (1971) Limited, responsible for engines both for Blue Streak and Black Arrow, wonders if the implications of successive Governments' actions are fully realized. By the mid-1970's — unless further Europa 2 launchers are required beyond those contracted for the 2 Franco-German Symphonie communications satellites in 1972-73 and payloads that may be approved by ESRO, there will in any case be no significant work on liquid propellant rockets thereafter in this country.



Prospero, launched by Black Arrow R.3 on 28 Oct. 1971, was designed primarily to test equipment for future space vehicles. This included PCM telemetry, power supplies, solar cells and protective finishes. Prime contractors were the British Aircraft Corporation and Marconi Space and Defence Systems. The Royal Aircraft Establishment acted as co-ordinating design authority. The only purely scientific experiment aboard is Birmingham's University's micro-meteoroid counter developed in conjunction with BAC's Electronic and Space Systems Group.

Department of Trade and Industry

The high skills that have been developed in Britain, and the considerable investment in development and test facilities, will have gone for nought. Henceforth, the centres of any European rocket business will be in France and West Germany.

What, then, is to be Britain's future role?

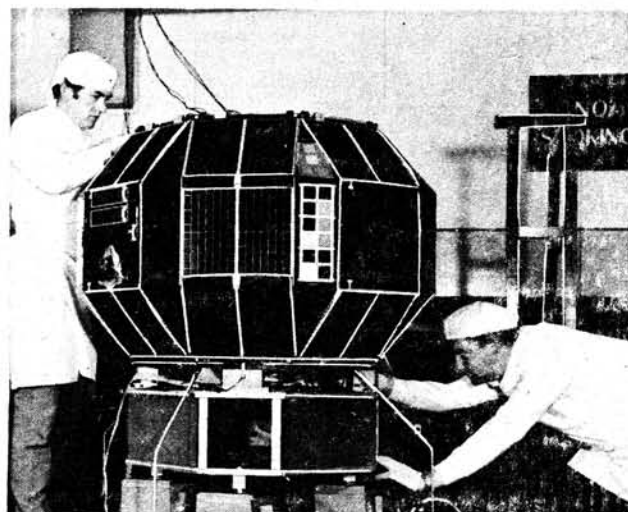
The decision not to continue with the production of Black Arrow was an early outcome of the current Government review of the National Space Technology Programme, which is expected to be completed early this year. According to the Ministry of Trade and Industry, the review was undertaken 'to see whether the NSTP was properly gauged to meet the needs of the UK space industry in the rapidly changing competitive situation of space technology. The views of the main spacecraft contractors were invited and were being taken into account'.

Another early outcome of the review was the decision to begin the full development phase of the 2nd technological satellite, X-4, for which Hawker Siddeley Dynamics are acting as prime contractor. X-4 is intended primarily to demonstrate in orbit a 3-axis attitude control system such as will be needed in future applications satellites.

Satellite X-4 is now scheduled to be launched in 1974 on a NASA Scout rocket from the United States Western Test Range.

The main questions being examined in the remainder of the Government review are whether to continue after X-4 with a programme of comparatively small satellites for near-Earth orbit, or to turn to the development of considerably larger satellites which could prove in geo-stationary orbit the technology of future applications satellites.

To this end, a contract to study the design of a Geo-stationary Technology Satellite (GTS) was recently placed with industry by the Ministry of Defence Procurement Executive on behalf of DTI. All the three main UK spacecraft con-



Preparing the 66 kg Prospero (X-3) technology satellite for vibration testing at BAC's Bristol test facility.

British Aircraft Corporation

tractors — British Aircraft Corporation, Hawker-Siddeley Dynamics and Marconi Space and Defence Systems — are participating in this study.

At the time of the cancellation of Black Arrow, expenditure in industry on the National Space Technology Programme was running at the rate of some £4 million a year. Of this some £1.75 m. was accounted for by satellite development work, £0.25 m. by basic technology contracts, and £2.0 m. by Black Arrow. Total UK space expenditures are shown in Table 2.

Table 2. U.K. Expenditure On Space Activities (£000's)*

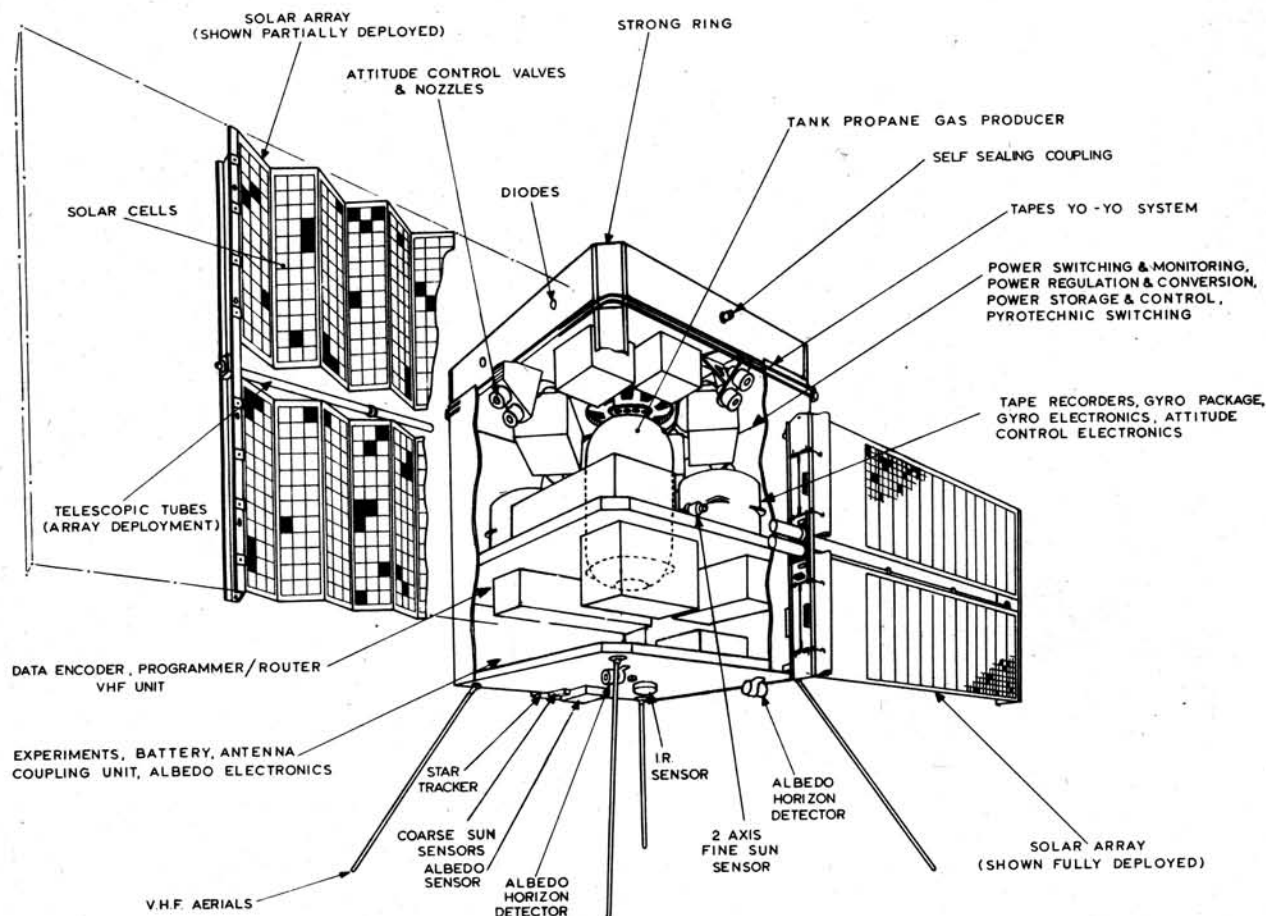
	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72 (Estimates)
<i>International Civil Programmes</i>						
ELDO (1)	12,540	8,750	9,640	8,170	2,390	—
ESRO (2)	3,850	4,500	5,000	5,200	5,620	7,370
INTELSAT (3)	800	600	1,040	1,030	720	770
POST-APOLLO STUDIES	—	—	—	—	100	50
	17,190	13,850	15,680	14,400	8,830	8,190
<i>National Programme</i>						
Defence	3,500	4,000	10,700	5,360	6,190	10,100
Commercial Satellite Communications (Post Office Earth Terminals)	1,070	1,170	1,340	1,300	940	3,110
Scientific Space Research	2,230	1,960	2,350	2,930	4,320	4,530
Space Technology and other expenditure not included above	2,770	3,170	4,110	3,830	4,160	5,260
	9,570	10,300	18,500	13,420	15,610	23,000
Total space	26,760	24,150	34,180	27,820	24,440	31,190

Notes: (1) Contribution to the Organisation (limited to £11 million as from 1st January 1969).

(2) Includes £100,000 for applications studies in 1969/70 and a total of £400,000 in 1970/71 for applications studies, applied research and applications satellites (Communications and Aeronautical).

(3) INTELSAT figures are the United Kingdom quota payments to the Organisation less United Kingdom revenue receipts from the Organisation.

* Reproduced from Minutes of Evidence Taken Before the Select Committee on Science and Technology, Sub-Committee B, 2 Feb, 1971.



Principal features of the X-4 technology satellite which will test a new 3-axis attitude control system and extensible solar arrays.

Hawker Siddeley Dynamics

What seems imperative is that the fragmentation of departments interested in Space within the various Ministries should be repaired without delay. The situation was bad enough in the days of the Wilson Administration, but following the recent fracture of the Ministry of Aviation Supply into branches of the Ministry of Trade and Industry and the Ministry of Defence, each has its own Director of Space, with separate staff, and all the duplication this entails. A streamlining of the Government administrative machinery seems to be the only sensible course.

What also remains to be decided is whether Britain is to participate with the United States in the post-Apollo programme.

It is to be hoped that wiser councils will prevail in this area of aerospace development than those which dictated space policy in the Sixties. Token Government support has been given to British Aircraft Corporation and Hawker-Siddeley to participate with American companies in Phase B studies of the space shuttle. From all accounts the modest British contributions have been well received in the United States.

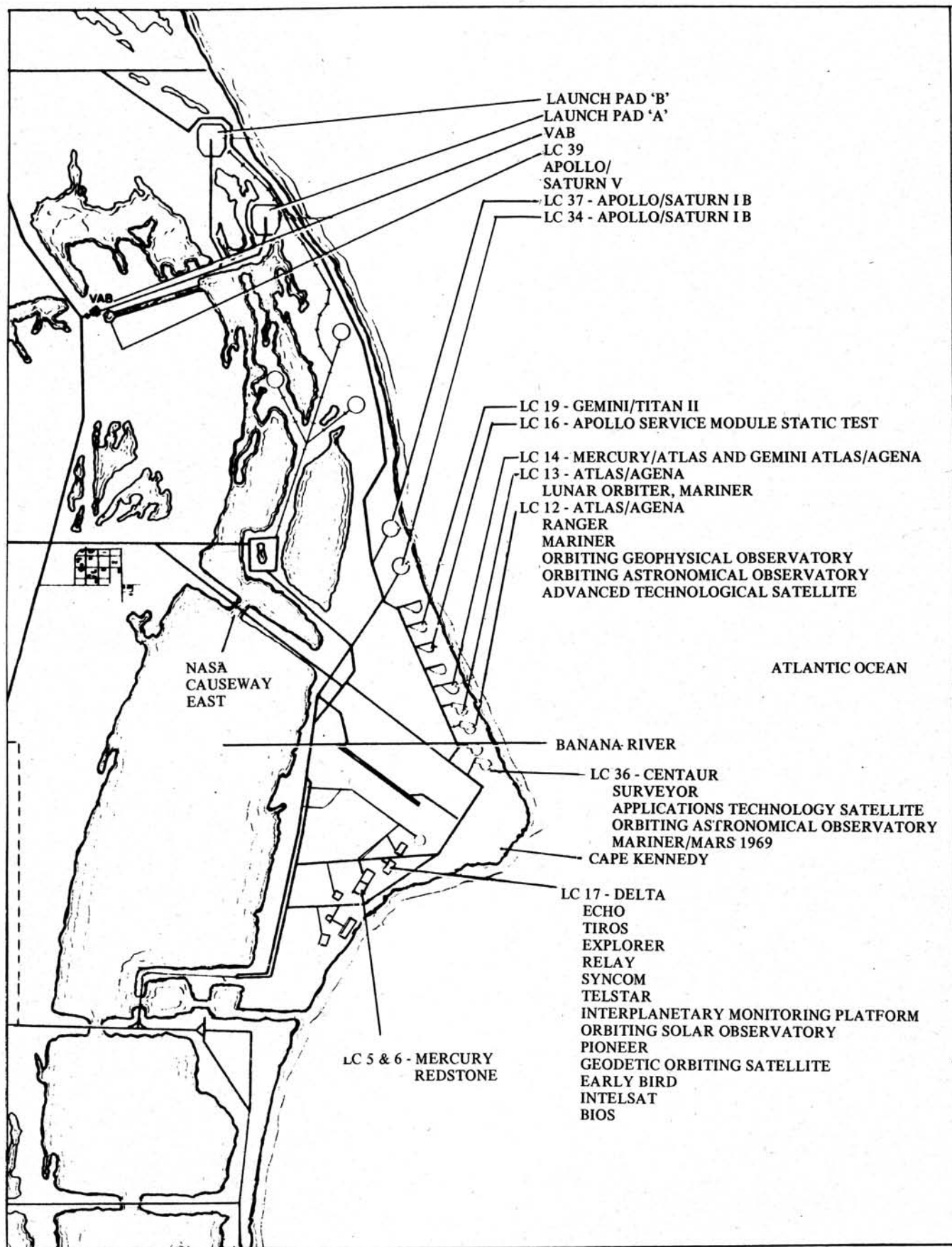
Britain has also been represented in ESRO studies for the Research Applications Module (RAM) and in ELDO studies for the Space Tug.

What seems vital is that Britain and her European partners should take immediate steps to formalize the amalgamation

of all European space interests — ESRO, ELDO, CETS, etc. — so that maximum effort can be directed to major programmes and properly co-ordinated.

Above all, a firm decision is required on the part Europe is to play with the United States in post-Apollo. Once U.S. policy in this programme is clearly defined (hopefully by mid-summer 1972) Europe should be ready to make a collective response, whether in the sphere of the space shuttle or the various supporting programmes. A large number of important research and development facilities have been constructed by European firms and agencies which are under-employed. In post-Apollo they represent valuable assets with which Europe could begin to enter the mainstream of space technology. The trend begun with Intelsat 4, one of which was assembled and tested at the new Spacecraft Assembly Building by B.A.C. at Bristol, can be continued within a unified U.S.-European post-Apollo programme.

Fate decreed that we should successfully achieve the first all-British space launching (which will also be our last) on the very day that Parliament voted overwhelmingly to join the European Economic Community. Let us now see that our contribution to the European space community will be effective in the major task of creating, with our American friends, an economic space transportation system from which, surely, huge benefits will flow for all mankind.



typical launch. A prominent notice told photographers what exposure and speed to allow for a wide variety of films.

Of more interest than might be expected was the specially constructed crawlerway connecting the Vertical Assembly Building with the actual launch pad. This consists of two 40 ft. wide lanes separated by a 50 ft. wide grass strip. The overall width of the roadway is thus 130 ft, or about that of an 8-lane motorway.

Still apparent were the indentations made by the Giant Crawler when it had removed the Mobile Service Structure the previous night, a few hours before lift-off. When loaded with a Mobile Launcher and a Saturn/Apollo, the combined weight with the Crawler is some 9,000 tons, resulting in a track loading of about 6 tons/sq.ft. This is sufficient to crush the surface layer of stones.

Parked in a side junction were the Crawler Transporter and Mobile Service Structure. The latter, 402 ft. high and weighing 4,500 tons, contains 5 service platforms that provide access to the space vehicle for final servicing at the launch pad. The structure was resting on four 22 ft. high steel pillars, similar to those used at the launch pad, and similar to those also used to support the Mobile Launcher, from which Saturn V actually lifts off.

Of particular interest was the Transporter, about which we had heard so much. Our first impression was one of disappointment, as its size — it is 131 ft. long by 114 ft. wide — was not readily apparent. However, this feeling soon disappeared as we walked up close to one of the eight 40 ft. long tracked units on which it moved.

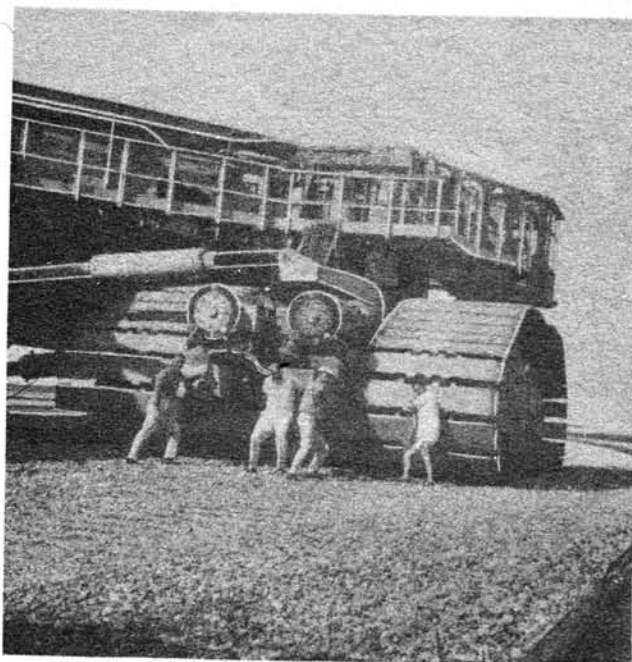
The Transporter has a speed of 1 mph when loaded; a major problem when it was underway was ensuring that the driver did not fall asleep! Both the Mobile Launcher and the Mobile Service Structure have to be located very accurately when being positioned on the launch pad, and to eliminate the necessity of the driver having to back out for a second attempt the vehicle is guided up the ramp by an on-board computer for the last few hundred critical feet.

The industrial area is located some 5 miles south of the Saturn V Launch Complex 39, and planned so that all functions not required at the Complex itself are grouped together for ease of administration and efficient operation. It consisted of several blocks of pleasantly designed buildings; in this area at least the local 'jungle' was kept well at bay.

The largest building in the area was that for Manned Spacecraft operations, a facility used for the modification, assembly and non-hazardous checkout of Apollo spacecraft. It also provides astronaut quarters and medical facilities; spacecraft testing stations and complete supporting laboratories. It was strange to think that only the previous night rooms in this building were occupied by astronauts David Scott, James Irwin and Alfred Worden, now well on their way to Hadley Rille on the Moon.

Nearby was the Headquarters Buildings, the administrative centre for spacecraft operations. Inside we breathed in the pleasantly cool air of efficient conditioning, and made our way along a spotless corridor to the post office, to mail some covers which in due course would be franked with the much sought after Cape Kennedy postmark and bearing the date of a major launch.

A small souvenir shop for NASA employees caught our attention and we spent several minutes admiring the items on display. Particularly appropriate was the condiment set in the shape of Mercury and Gemini spacecraft. Unfortunately for our friends back in England — but fortunately for our



Giant Crawler. Despite its vast bulk — the Transporter is 131 ft. long and 114 ft. wide — the size was not really evident until one walked close to it. In this picture a BIS group stands beside one of the 4 double-track units on which the 3,000-ton vehicle moves. Each track unit is 10 ft. high and 40 ft. long. There are 57 shoes, each weighing one ton, on each track.

Further recollections of the Apollo 15 excursion to Cape Kennedy will be given by Maurice F. Allward in an illustrated talk at the Space Study Meeting on 10 Feb. (see back cover). Details of last-minute arrangements for the Apollo 16 tour — which leaves from Gatwick on 12 Mar. — will also be available at this meeting.

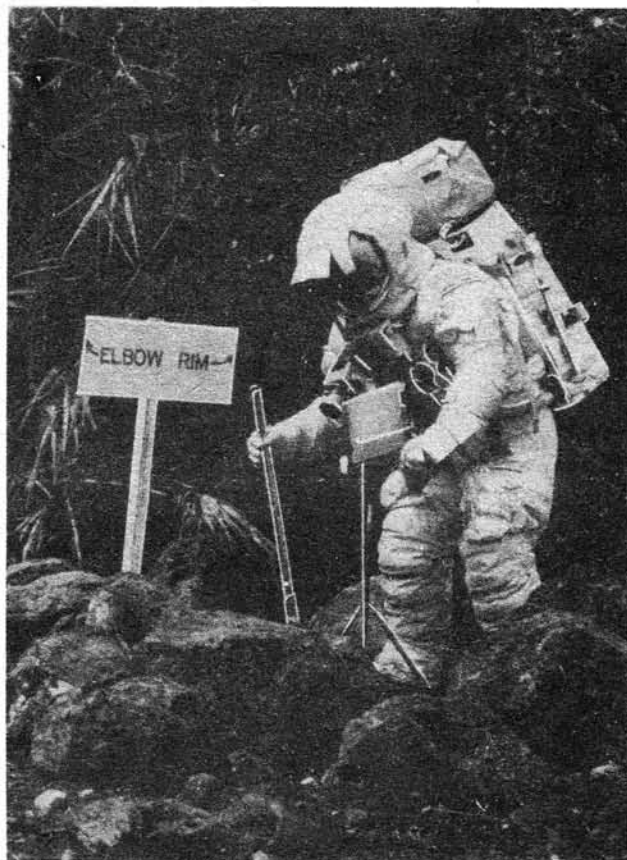
pockets at the time — the shop was closed.

Air Force Space Museum

Our tour nearly over, we drove south past Cape Kennedy Air Force Station within the boundary of which is located the Air Force Space Museum.

This museum was apparently started by the private efforts of a sergeant who, when he spotted obsolete hardware being left to rot or taken away for scrap, asked if he could have it. The concrete bases on which many exhibits rest were made from material 'left over' from official construction works, as were many of the pathways. The result is a unique collection of old and modern missiles and spacecraft on display to the public.

In the middle of the site is a small concrete building which, we were astonished to learn, was the actual blockhouse used to control the launch of the sub-orbital flight made by Alan Shepard in a Mercury capsule in May 1961. Barely 100 ft. away was a structure resembling an oil derrick rig. Not surprising perhaps, because that is what it originally was. It was converted into a gantry for the Shepard shot. In front was a small stand and conical metal thrust deflector — the only items of launch pad equipment needed in those early days.



This picture of Harrison Schmitt again emphasises the extent of tropical vegetation amid the training areas and launch sites.

Other exhibits on display included:

Atlas	Boiler plate Mercury
Gemini	Juno I and Explorer I
Juno II	Rocket sled
START lifting body	Thor Delta
Thor IRBM	Titan

The museum grounds include Complex 5/6, used not only for the sub-orbital flight of Shepard, but also that of Virgil Grissom, and Pads 26A and B. The latter was used to launch Explorer I, America's first satellite. Complex 26 was the scene of many other early satellite launchings; also of the monkeys Able and Baker.

The blockhouse was, unfortunately, closed and we were unable to view the firing room which has been restored to resemble its operational state.

Thus ended a day of technical achievement and excitement we shall long remember.

APOLLO 16 TIMELINE

Apollo 16 astronauts John W. Young, Thomas K. Mattingly II, and Charles M. Duke will lift off from the Kennedy Space Center at 1:03 pm EST on 17 Mar., with the objective

Apollo 16 Preliminary Timeline

Event	March Date	EST	GMT
Launch	17	1:03 pm	6:03 pm
Translunar Injection	17	3:40 pm	8:40 pm
Lunar Orbit Insertion	20	5:10 pm	10:10 pm
Descent Orbit Insertion	20	9:14 pm	2:14 am (21 Mar.)
Lunar Landing	21	5:25 pm	10:25 pm
Start EVA 1	21	9:18 pm	2:18 am (22 Mar.)
Start EVA 2	22	7:48 pm	00:48 am (23 Mar.)
Start EVA 3	23	7:13 pm	0:13 am (24 Mar.)
Lunar Launch	24	6:23 pm	11:23 pm
Transearth Injection	26	8:56 pm	1:56 am
Transearth Coast EVA (film retrieval)	27	4:33 pm	9:33 pm
Earth Landing	29	4:14 pm	9:14 pm

of increasing man's knowledge of his Solar System by studying the evolutionary records preserved on the Moon. Such records on Earth were long ago destroyed by natural events. The launching will be witnessed by another British group organised by Transolar Travel in conjunction with the British Interplanetary Society. Members wishing to join the party, which leaves Gatwick on 12 Mar. by BUA/Caledonian 707, are recommended to contact the Executive Secretary without delay.

Exploration of the Descartes area will complement data gathered from earlier Apollo missions by sampling from 2 distinctive lunar formations, by emplacement of another scientific experiment station on the lunar surface, and by conducting a series of experiments from lunar orbit and during translunar and transearth flight.

The 2nd and 3rd lunar surface expeditions are tentatively planned to begin at about 7:48 pm and 7:13 pm EST on 22 and 23 Mar., respectively. Astronauts Young and Duke will use the Lunar Roving Vehicle on all 3 of the 7 hr. trips. The Lunar Module is scheduled for lunar liftoff at 6:23 pm EST on 24 Mar., after 73 hours on the Moon.

Scientific experiments in the Apollo Command-Service Modules will be operated by astronaut Mattingly during much of the 147½ hours of lunar orbital flight.

Mattingly will manoeuvre outside the Apollo spacecraft to retrieve films from the Service Module experiment bay at about 4:33 pm EST on 17 Mar., some 20 hours after beginning the return flight to Earth.

The planned splashdown point is about 9° South Latitude and 169.5° West Longitude in the Pacific Ocean at 4:14 pm EST, on 29 Mar. Total mission duration is 291 hr. and 11 min.

The Descartes landing site is about 9 degrees South and 15.5 degrees East of the center of the Moon as viewed from Earth.

Spacecraft Commander is Navy Captain Young, who completed 2 Gemini and the Apollo 10 missions prior to this assignment. Command Module Pilot is Lieutenant Commander Mattingly and Lunar Module Pilot is Air Force Lieutenant Colonel Duke. Neither Mattingly nor Duke have flown in space before.

DR. J. P. VINTI

MATHEMATICAL PHYSICIST

Introduction

Partly by choice and partly by chance, I proceeded from one branch of mathematical physics to another. I began in theoretical atomic physics, the newest branch at the time, next went into classical physics, and have now reached the most classical of all branches, celestial mechanics, which has received a new life in the space age.

Education

It was at Rogers High School in Newport, Rhode Island, that I developed interests in chemistry and geometry that led me to decide on a career in science, and, after I entered the Massachusetts Institute of Technology, I chose chemistry as my major at the end of my freshman year. A required summer course in qualitative analysis was fun, although the instructor was rough and tough and my classmates kept telling me that what chemists did was analyse all day long. I wanted to do research. When I reached quantitative analysis, I could not get interested in trying to find fading end points in titration and trying to precipitate the most insoluble substances out of solution. So far as I could see, none of this was aimed at understanding nature.

At the beginning of my junior year, I therefore decided to change to mathematical physics, and actually finished my undergraduate course as a mathematics major, to avoid making up a few courses that I didn't need.

After receiving my S.B. degree and having been awarded a James Savage Fellowship at M.I.T., I enrolled as a graduate student in physics. Of all the studies that I pursued, I found Hamiltonian mechanics among the most interesting. Then, as now, the Hamiltonian - Jacobi equation was regarded by most physicists only as a point of departure for quantum mechanics. Many years later, however, I was to be one of the first people to apply it effectively to an important practical problem in orbital mechanics.

I began my doctoral dissertation on atomic wave functions under the physicist Rudolph M. Langer, who has been my friend ever since. After he left, I finished my thesis under Philip Morse, now famous for many things, but from my own point of view, his most pertinent achievement is the Morse Potential for diatomic molecules. This kind of approach, that of finding a 'solvable problem', appeared in the additional thesis topic that he suggested and has been a dominant factor in my later scientific career.

A Transitional Period

After the award of a Doctor of Science degree in physics from M.I.T., some years elapsed before I began my first long job, at Aberdeen Proving Ground. First I spent 2 years as a postdoctoral research fellow at the University of Pennsylvania. Of the several papers that resulted, the most important for space science was a calculation of the continuous absorption spectrum of helium. At astronomical meetings people familiar with my later papers on orbits often ask if I am the same person who wrote that paper. I still find frequent references in the literature to much of my early work in atomic physics, written in the period between my graduate work and my job at Aberdeen.

I next worked at M.I.T. as a special research assistant on a proposed application of the Stirling heat engine and carried it far enough to find a bottleneck in the heat transfer, a difficulty that the Dutch are still finding today. Shortly

Dr. J.P. Vinti



thereafter I did the first calculations for large water-cooled electromagnets. Such electromagnets were later used by Francis Bitter in setting up the National Magnet Laboratory.

In those depression years I then took on several academic jobs, the most interesting of which was an instructorship at Brown University. As there was so little money available, I was called a part-time instructor, but I found myself busy teaching quantum mechanics and running the seminar on theoretical physics.

Aberdeen Proving Ground

Shortly before the beginning of World War II, I became a research physicist at Aberdeen Proving Ground. My first work there was experimental, developing a method for testing strain gauges, building an electric wave filter to get rid of noise on chronograph lines, and measuring electromotive forces generated by magnetized projectiles going through chronograph coils. From these projects I was led to revise the theory of the solenoid chronograph for measuring the velocities of projectiles.

I then went into interior ballistics for many years. I made a number of contributions in this field. At that time there were few who contributed to this field, e.g. Hirschfelder in the US and Corner in the UK. This work had to do with guns. It was not until some time later that there appeared the extensive work on the interior ballistics of rockets that concerns space scientists.

Beginning Space Research

With the coming of the atomic age I became restless, as I felt that I was working in an obsolescent field. Knowing about this, my friend Alfred Hodge, who had patiently supervised my earlier and somewhat clumsy experimental work, suggested that I join his group to work on the theory of ballistic measurements for missiles. With them I did the theory of electronic missile acquisition, antenna theory, a long treatment of the multipath propagation of multitone frequency - modulated waves, and the theory of the effects of eddy currents on the spins of artificial satellites. The latter showed that the induced magnetic moment not only slows down the spin, but also turns its axis.

All the work I did at Aberdeen is now unclassified. The multipath report led to a monograph published by the

Office of Technical Services and to journal papers on antennas and on Bessel functions, the last in collaboration with T. Leser. Some earlier work on the multiple scattering of gamma rays, which had somehow got sandwiched in among other things, led to published papers on Legendre polynomials and on gamma ray scattering.

While at Aberdeen I partially resumed my academic career, serving at various times as lecturer in physics and mathematics for the Universities of Delaware and Maryland. I also became acquainted with the many distinguished scientists who worked at Aberdeen during and after the war. Of all my associates, however, it was Boris Garfinkel, an astronomer, and Joel Brenner, a mathematician, who had the greatest influence on my subsequent career. As I worked on the spins of artificial satellites, I had to look into their orbits. Boris helped direct my efforts in celestial mechanics and taught me a good deal then and later, so much indeed that we eventually became friendly rivals in the field of satellite orbits.

Satellite Orbits

In 1957 a chance contact with a former Aberdeen associate led me to the Applied Mathematics Division of the National Bureau of Standards in Washington. I went there with a promotion and in a few years reached the highest Civil Service grade that a scientist could attain without having to do administrative work.

Shortly after going to NBS, I encountered a problem presented by the first Sputnik. This was to improve the theory of the change in its orbital inclination that was produced by the drag of the rotating atmosphere. After doing this, I became interested in the main effects of drag on the orbit. I worked on the problem for some time and then an unexpected letter from Joel Brenner drew my attention to a meeting at NASA, which I attended. The papers presented there made the drag appear to be intractable to mathematical analysis, because of the complicated dependence of air density on many factors. As I met Joel Brenner at the close of the meeting, he made the obvious statement that Earth oblateness was really much more important than drag in affecting the orbit of a satellite at the altitudes then attained, about 300 miles. But he remarked that he had found an 'exact solution' for the effects of oblateness. I use quotation marks, because every scientist knows that the actual phenomena of nature are extremely complicated, even though its ultimate underlying laws may be simple. What one does to obtain an 'exact solution' in mathematical physics is always to dissect off a bit of nature, as if along a natural cleavage plane, and solve that system exactly.

To have some fun, I postulated that Brenner was correct and said to myself 'Now that I know it can be done I can do it'. This sort of feeling had been current since 1945. 'So, I'll find the solution. If it's the same as Joel's, I'll let it go. If it's not, I'll publish it'. Well, I did find a solution and fortunately it had nothing to do with Joel's work, which turned out to be related to something quite different, namely exact error bounds in a Hansen method. At this point I dropped my investigation of the drag and turned to the purely gravitational problem for a satellite orbit.

To obtain an exact solution I knew I had to solve the Hamilton-Jacobi equation, called HJ henceforth. Sterne and

Garfinkel had already done this, with the use of non-central forces, and had thus obtained 'reference orbits' better than the simple elliptic orbit. My graduate years at M.I.T. however, had made me familiar with another important feature of an 'exact solution'. In colloquia Morse and J.A. Stratton (later M.I.T.'s president) had rather fully explored the then new developments in separable systems. These separable systems dated back to Staekel, but Eisenhart at Princeton had recently investigated and catalogued the 11 systems of coordinates in which the main partial differential equations of physics can be separated. The M.I.T., discussions emphasized the importance of choosing that system which has the most appropriate symmetry, if one wishes to find a useful 'exact solution'. Thinking in this way, I saw that the oblate spheroidal system ought to be the best for an oblate and almost axially-symmetric planet like the Earth.

It was easy to find the general form in oblate spheroidal coordinates, for an axially-symmetric Earth potential, that would separate HJ. I worked it out and then found that it was already listed in the book by Morse and Feshbach. But then I added a refinement, the feature that distinguishes my method from other 'intermediaries'. I required that the potential should satisfy Laplace's equation. Three disposable parameters permitted a fit of the potential through the 2nd zonal harmonic in the spherical harmonic expansion, with a concomitant unfitted bonus of 2/3 of the 4th zonal harmonic. This meant that I had been able to include the complete effect of earth flattening in the solvable problem, plus a little more. The higher harmonics of the model are very small. They are also so small for the actual Earth that the resulting spheroidal potential is accurate everywhere outside the Earth, to a few parts in a million.

I sent the 1st report of this work to *Physical Review Letters*, which received it on 27 Apr. 1959 and published it on 1 July 1959. The Soviet scientist Kislik published a similar paper in 1960. In 1963 the Soviet scientists, Aksenov, Grebenikov, and Demin, published a paper which I acknowledged when I followed a hint of theirs that enabled me to incorporate the 3rd zonal harmonic, or pear shape, into my spheroidal method.

Through the years 1959-1969 I published a series of papers in which I put the theory in such a form as to obtain final algorithms for calculating satellite orbits, to the accuracy required for tracking purposes. (No method is yet sufficiently good for calculating an orbit to the 10 cm. accuracy desired in an orbital base line for satellite geodesy or oceanography). Izsak made an important contribution to the topic, introducing the quantities that I use as constant orbital elements, but using elliptic functions and incomplete elliptic integrals, whose explicit use I have carefully avoided. Many other people have now contributed to or applied the spheroidal method, including Allen, Batra, Bonavito, Borchers, Callender, Getchell, Knolle, Kyner, Lang, Marchal, O'Mathuna, Sherrill, Wadsworth, Walden, Watson, and others, plus the Soviet school mentioned above. There is another name for the spheroidal method, besides my own, which has a certain mathematical foundation, but no physical meaning. Some authors prefer to call it the 'generalized problem of 2 fixed centers'.

Among the above authors, Bonavito, Walden, and Watson have developed appropriate methods for differential corrections and for orbit determination. The latter topic is especially important. Besides having speed, accuracy, and applicability to orbits with all eccentricities and inclinations, the

spheroidal method luckily facilitates rapid and dependable determination of the orbital constants. One is not likely to lose a satellite, if one uses the spheroidal method in tracking it. Bonavito and his colleagues have also recently extended the usefulness of the theory for low altitudes, by showing how to put drag into the calculations.

While I was at NBS, my work on orbits led to an award from the Bureau and election to Fellowship in various scientific societies. It also helped me to resume my part-time academic career, as professorial lecturer at Georgetown University and adjunct Professor at the Catholic University of America.

Recent Activities

In 1965 I accepted a Professorship of applied mathematics at North Carolina State University in Raleigh, where I taught celestial mechanics. After 8 interesting years in Washington, however, I did not feel at home in Raleigh and soon returned to New England.

At M.I.T. I have since combined teaching celestial mechanics and doing research in the Measurement Systems Laboratory. My latest paper on the spheroidal method incorporated rectangular coordinates into the algorithm, thus eliminating spurious longitude-induced difficulties near a pole in a polar or nearly polar orbit. Two recent papers on the old problem of the stability of free rotation of a rigid body led to some new quantitative results. Another recent report shows the feasibility of representing the higher

harmonics of the Earth's gravitational field by means of a monopole layer on a spherical surface just containing the Earth. These higher harmonics amount to only a few parts in a million, but there are hundreds of them that have to be accounted for in calculating an accurate satellite orbit as a base line for satellite geodesy.

In 1963, Rudolph Langer and I had published a paper setting forth some of the experiments that an astronaut could do in manned satellites of the Mercury type. It attracted no attention at the time, but some of the ideas that we dealt with are now coming into the picture. Recently the Measurement Systems Laboratory, under Professor Winston Markey and at the suggestion of our scientist-astronaut Dr. Philip Chapman, has been concerned with devising experiments for possible performance in a large manned orbiting laboratory. With the cooperation of my colleague Leonard Wilk, I have recently completed the analysis of an experimental method for determining the gravitational constant G in such an orbiting laboratory. The interest here is eventually to be able to search for possible variations of G with gravitational potential, in order to test Dicke's modification of general relativity.

Among more practical lines the laboratory is now looking into the uses of satellites for various surveys, e.g. for air traffic control and for geodesy and oceanography. The fantastic requirement of 10 cm accuracy in mean ocean levels may soon be met on the instrumental side. The correspondingly accurate calculation of a satellite orbit for a base line, however, presents a challenge to celestial mechanics.

THE SHUTTLE — AN ECONOMIC APPRAISAL

By David Baker

Introduction

Throughout the 1960's man was able to set forth on the first voyages of celestial discovery, using various contraptions born of his technological ingenuity. These were initial, embryonic steps, hampered by the costly throw-away approach dictated by the only transportation system then feasible. Hopefully, the 1970's will be remembered for the introduction of a radical new approach toward reducing the costs of spaceflight, bringing those same journeys within reach of the 'non-astronaut' and setting the scene for a whole new generation of orbital space vehicles.

Undoubtedly the overriding displeasure with manned spaceflight stems from the high costs involved. Manned spacecraft are, by virtue of their large mass and unparalleled complexity, difficult to equate with a concept demanding high return per unit cost. It is readily becoming apparent, through lessons learned from Apollo, that man can best be utilised in the role of aerospace pilot, rather than being the singular objective of a mission. As the conveyor of sophisticated orbital craft that can be visited for resupply or periodic maintenance, man applies his unique skills in a way superior to the electronic masterminds of the conventional launch vehicle. This, after all, has always been the desirable goal, hitherto so difficult to transform into practice. Economically it has been seen that the reusable concept offers a whole new range of possibilities. Technology is now in a position to seriously challenge the sceptic who

prophesied that space activities would always remain incapable of justifying their own high costs.

For any discussion of economic approaches to spaceflight we must first consider the level of costs involved and determine where the responsibility for such expenditure lies. Fig. 1 presents a logarithmic scale of cost comparisons relating to the NASA programmes. The annual US expenditure on space activities runs at less than $10^{9.5}$ dollars, nearly 2 orders of magnitude below the federal budget. Salaries and wages amount to 3 or 5 powers of 10 per annum. On this scale, the development cost of a Saturn V launch vehicle is only marginally in excess of that required for a supersonic transport. Indeed, the unit cost of a Saturn V is about 10^8 dollars and a supersonic transport about $10^{7.5}$. Thus, the increased development and unit costs of a conventional launch vehicle are acceptably proportional to the increased technology. However, this situation is reversed when we compare the flight costs of space and air transportation systems. A Boeing 707 averages about 10^3 dollars per flight, while a single Saturn V absorbs more than 10^8 dollars, 5 orders of magnitude higher and at a log figure approaching the entire development cost.

This gap would widen if a citizen were to buy a ticket first for a flight in a commercial airliner and then on a Saturn V. For the former he would pay an average $10^{1.5}$ dollars, for the latter about $10^{8.5}$. At last the problem

becomes apparent. The single operation of a Saturn V, or for that matter any conventional launch vehicle, absorbs all the enormous loss compared with an unlimited reusability. The SST would require a development cost only 0.5 power magnitude less than that for a Saturn V - yet it is expected to provide a financial return or at least break even. The problem, therefore, is simplified. Extend the possibilities of reusability to conventional launch cycles and the probability of amortisation is increased.

Determining the Reusability Rate

Several studies have been made in an effort to determine the required reusability rate for achieving a maximum saving. If approached from the viewpoint of economics an endless lifetime would obviously be the most desirable. However, this is not feasible for obvious practical reasons. So, a compromise is necessary. The resulting decision will be heavily influenced by a prediction on the number of flights anticipated during a given period of time. We shall return to this later.

Before we can fully appreciate the problems associated with reusability in space vehicles we must briefly remind ourselves of the development, and potential flexibility, inherent in launch vehicle design.

As a rocket stands on the pad, complete with propellant and payload, we can divide the gross weight W into 3 components. The payload is represented by P , the physical stages of the vehicle together with engines, plumbing and instrumentation, by S . The propellant carried in the tanks is represented by F . Using the fundamental equation for rocket vehicle performance,

$$V = -C \log_e \left(\frac{s}{W} + \frac{p}{W} \right)$$

where V is the integrated velocity of the vehicle and C is

the exhaust velocity of the atomised propellant, we begin to see the problem in perspective.

One of the principal offenders in the search for full reusability has been high structure to weight ratios. In the early days of rocketry S/W of 0.24 was average for most launch vehicles. Today it is practical to think in terms of S/W ratios of 0.06 or less, as demonstrated by the Saturn V. If we apply to this the exhaust velocity of the engines, which today stands at about 10K ft/sec, we can begin to understand the dilemma which dogged early proponents of reusability. Plotting our net result against the ratio of vehicle velocity versus the ratio of gross weight to payload, we find that a V/C of 2.3 is required to achieve a minimum orbit. With the low S/W ratio and high exhaust velocities of present day rockets we see that we can achieve a V/C of 2.7, well beyond the necessary value for a single stage concept. This happy situation has not always prevailed, however. An early design engineer, planning the launch vehicle flight profile for a given payload, was dealing with a S/W ratio of 0.24 and a C of 8K ft/sec. Targeting for a velocity of 26K ft/sec he therefore required a V/C of 2.3. With his single stage the engineer would rapidly discover that he would never achieve more than 65% of orbital velocity - limited by the asymptotic V/C value of 1.43. The problem was well understood. The solution was more elusive.

In concept at least, the answer was simplicity itself. Why not provide a larger vehicle to carry the upper portions to altitudes where they could then start operating with the added advantage of altitude and velocity? It was, after all, only the same technique as launching east to gain the advantage of the Earth's rotation. By sequentially discarding used weight, reducing the mass, and improving the thrust-to-weight ratio, it was possible for a 3-stage vehicle to reach a V/C in excess of 3.0, realising the possibility of interplanetary flight.

The modified performance equation with n number of stages thus becomes:

$$V = -C \log_e \left[\frac{s}{W} + \left(\frac{p}{W} \right)^{1/n} \right] n$$

This is certainly a more promising picture than is implied by the previous equation. As an example, the Saturn V could accelerate a 700 lb payload to a velocity of 65K ft/sec, sufficient for a Hohmann transfer ellipse to the edge of the Solar System. This is achieved through the law of 'inverse concession'. That is, to achieve a higher velocity for a given S/W , merely decrease the payload-to-structure ratio. Fortunately the resultant curve is particularly sensitive to decreases in payload, although this has the disadvantage of causing a lot of head scratching when the payload grows.

As studies mature it becomes apparent that the best approach to a cheaper transportation system lies within the 2-stage fully reusable concept. The payload margin assumes a satisfactory value and the operational flexibility is suitably expanded. An optimum level of reusability dictates that each system be capable of cycling over a period of 100 missions. At this level the maximum amortisation of recurring costs is achieved. The difficulties of producing a vehicle to achieve reusable rates in excess of this figure would prolong development and prohibit an early return of non-recurring costs.

The shuttle is most readily seen as a cheaper method of transportation in heavy logistics supply roles. One recent study assumes a lunar orbit station by 1987. The annual cost of resupply using the current, expendable systems runs out to some 1,436 million dollars. A shuttle system would reduce this to 525 million dollars, saving 900 million dollars per annum. The former value would be an optimistic figure for project justification whereas the shuttle could introduce savings that may well cancel out the entire development cost of a lunar orbit station (assuming a follow-on technology

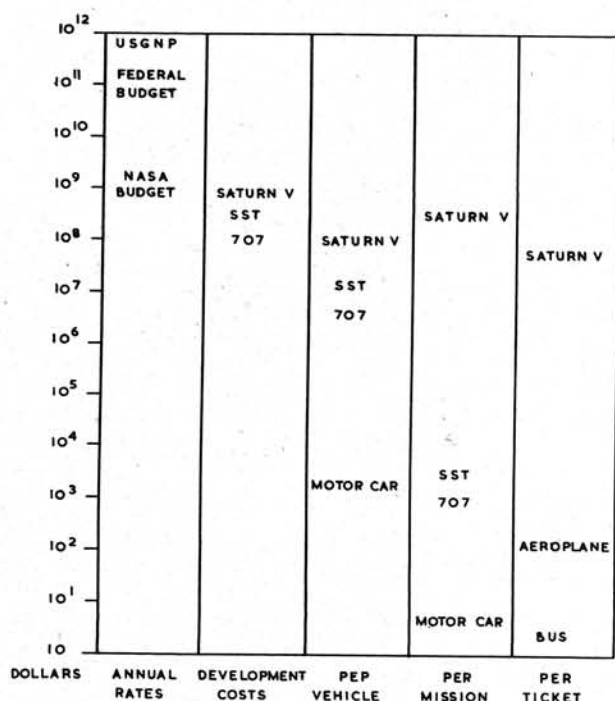


Fig. 1. Transportation cost comparison

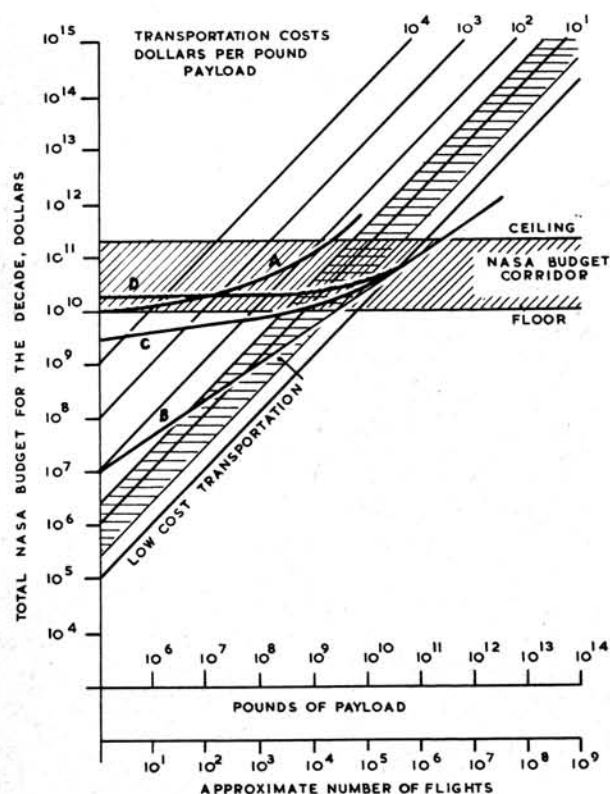


Fig. 2. Conventional launch vehicle costs versus a reusable transportation system.

from an Earth-orbit station).

Although NASA has laid tentative plans for programmes which would provide the shuttle with the most advantageous option for amortisation — logistics resupply — the cost of savings also impact upon a more conservative schedule. Indeed, it may be more realistic to virtually ignore the large scale introduction of expensive manned facilities. In the present climate, NASA is fiscally constrained to the point where scientific, applications, and Earth resources satellites are the only paths for development in the near future. Introduction of a space station at some time in the post-shuttle era would indeed emphasise the desirability of such a vehicle. For the rest of this discussion, however, we shall ignore the probable and deal only with practical possibilities.

Expanded orbit capabilities

A very promising feature of the shuttle proposals is the reduced constraints imposed on Earth satellites. No longer will hardware be so heavily limited in size and volume — payload diameters can be doubled and lengths trebled. NASA has already written a minimum cargo bay size of 15 ft x 60 ft into the studies contracted to industry. The use of standardised subsystem units will offer a greater superiority at lower cost, and these payload subsystems can be replaced in orbit. Finally, complete satellites can be withdrawn from orbit, refurbished and returned. Indeed, NASA has stipulated a minimum on-orbit lifetime of 7 days, opening the possibility of multiple maintenance and component replacement within the scope of one shuttle flight. A pressurised cargo bay can be readily utilised as a hanger/workshop for such activities.

We can now look at these prospects in more detail. Reduction of dimensional constraint is probably the best possibility for achieving cost reductions. However, it is

anticipated that development cost would fall by 20% over the initial 6 years of shuttle operations, and operational costs of satellite performance would fall by 30%. There is, therefore, the prospect of halving costs merely by relaxing the constraints on weight and volume. The principal factors in this estimate benefit from a less complex design, use of off-the shelf components, and simpler checkout procedures.

The second area of cost effectiveness concerns the opportunity to make repeated use of the shuttle's down-load capability. Planetary satellites can have but a single use at the present stage of development, but many satellites operating in low orbit and even synchronous orbits could be reused either in total or in part. A high percentage of payloads would be incapable of reuse, largely through redundancy of equipment type, but many could be reused 5 or 6 times over. It would require just 2 years of continuous shuttle operations to average a reuse factor of 2 for all NASA launch payloads. Assuming a 25% refurbishment rating on the initial cost of the satellite it would be possible to show high returns over current systems. One example, admittedly the most favourable case, would display a reduction of 41.2%. This assumes a lunar orbit station from 1978 to 1993 and reflects the added traffic loads attending such a project.

Hitherto, it has been impossible to provide a fly-back capability for the payload. The launch vehicle is, essentially a one-way approach that has severely hampered many projects in past years. Only recently Mariner 8 was lost because of guidance errors that, to a shuttle, would have returned the payload to an airstrip for re-launch. The 'intact-abort' made possible by a shuttle craft carries an extra bonus return of some 3.4% on annual investments.

Thus, we find that the distribution of savings from (a) relaxed weight and volume constraints, (b) multiple reuse of satellites, and (c) the intact abort capability, provides an average reduction of 60.9% per annum on all satellite projects. Transportation effects, a separate bonus, affords a 39.1% saving over conventional systems. Improvements in launch costs make the picture even more interesting. It costs about 800 dollars to launch 1 lb of payload with current expendable rockets. With the shuttle this would drop to some 75 dollars per pound.

Frequency of Shuttle Flight

Obviously, full realisation of the shuttle's economic feedback is enhanced by an increase in activity. Assuming the shuttle to be used for unmanned scientific, applications and Earth resources satellite launches, the initial year of operation would require some 34 flights increasing to a maximum of 58 per annum within 7 years. A more vigorous programme, including an Earth-orbit space station, place extra demands on the shuttle and raise the annual flight rate to 36 in the second year of operation and 66 seven years later. The introduction of a lunar-orbit space station toward the end of the next decade would raise the annual demand to 120 flights. Thus, it appears that the network of unmanned satellite launches planned for the next decade would alone justify a shuttle system. Disregarding the impact of space station and the resulting increase in logistics supply missions. Reference to fig 2 line D will show the amortisation level of 100 flights over the first decade of the shuttle operations. The minimum NASA schedule realises 714, with the introduction of a space station raising this to 770. With a lunar orbit station toward the end of this period the shuttle would fly 932 missions during the period of 1980 to 1990. Assuming a low level of 25 flights per year, and an initial operational capability in 1980, the shuttle would reach a break-even point in 1984. The higher paced programmes would force a return by 1982.

So far we have only considered the benefits to a limited programme of unmanned Earth orbital ventures. In wider

[Concluded on page 63]

SPACE SHUTTLE MAIN ENGINE

By David Dooling, Jr.

On 12 July 1971, the Rocketdyne Division of North American Rockwell Corporation was awarded the development and production contract for the Space Shuttle Main Engine (SSME). The National Aeronautics and Space Administration selected Rocketdyne over 2 other competitors, Aerojet General Corp., and the Pratt and Whitney Division of United Aircraft Corporation. With the exception of the Titan II engines (built by Aerojet), every US manned space launch has been powered by Rocketdyne engines, including the H-1, F-1, and J-2 of the Saturn family.

The SSME contract is worth 500 million dollars for the delivery of 36 engines by 1978, and potentially 1,000 million dollars for additional 64 engines by 1981. Twelve SSME's will be used in the shuttle booster and 2 or 3 in the orbiter. A common powerhead, burning liquid hydrogen (LH₂) and liquid oxygen (LOX), will be used for both. The booster engines will have a small (35:1 expansion ratio), fixed bell and the orbiter a short fixed bell with a moveable extension (150:1) to optimize thrust at high and low altitudes. Booster engine thrust will be 550,000 lb. a 15% increase over earlier designs. This was necessary to accommodate removeable air breathing engines on the orbiter without decreasing its payload capability (25,000 lb. to a 55° x 275 mi. circular orbit) and to ensure the orbiter's off-the-pad

abort capability. The orbiter engines, rated at 632,000 lb.in vacuum, will place that stage in a once-around, degraded orbit in the event of an abort.

The SSME may have at least one other use. The Space Division of North American Rockwell has been awarded a 250,000 Dollar Phase A contract to study a low cost reusable inter-orbit chemical stage. It would be launched by the shuttle booster and use the same engines as the shuttle to achieve orbit. Size of the stage and number of engines has not been determined. The stage would be capable of boosting 100,000 lb. to geosynchronous orbit and be used for lunar and unmanned planetary missions. A lifetime of 10 uses or 3 years, with quiescent periods of up to 6 months, is required. Refueling would take place in orbit by the shuttle orbiter. This stage is apparently intended for interim use until the Nuclear Orbit Transfer Stage (NOTS) becomes available. NOTS and its engine, NERVA, have run into funding delays in the Congress and NASA is unsure when it will become available for use.

When operational, the SSME will be the most efficient LOX/LH₂ rocket engine; reusability and light weight are primary considerations in its development. The horsepower-to-weight ratio will be 115:1, five times greater than any other LOX/LH₂ engine. One pound of engine weight saved

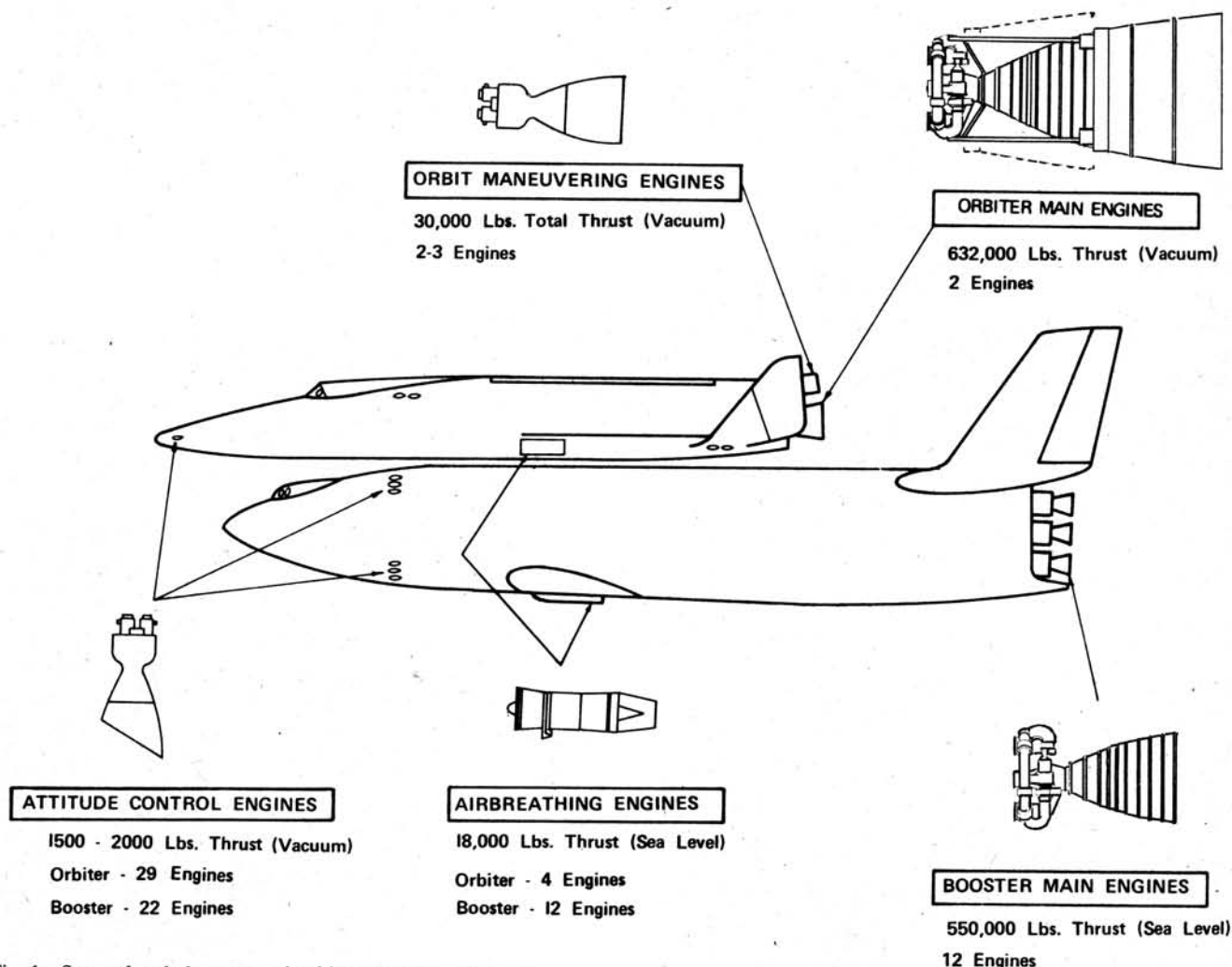


Fig. 1. Space shuttle booster and orbiter propulsion systems.

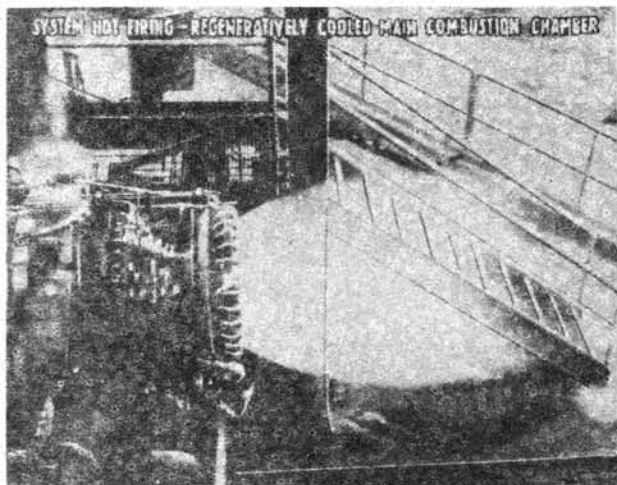


Fig. 2. Full scale test of SSME main combustion chamber. This unit has developed over 500,000 lb. of thrust.

will be worth 5 lb. of payload. Specific impulses (Isp) have been set at 436 lb-sec/lb. and 456 lb-sec/lb., for the booster and orbiter. A one second change in Isp will result in a 1100 lb. payload change. Rocketdyne has demonstrated, at its Reno, Nevada, tests site, a full scale SSME test unit that delivered 505,700 lb. thrust at an Isp of 465.9 lb-sec/lb. (the required thrust level was raised later). The throttle range has been set at 50% - 100% of normal power, continuous, and 109% normal for emergencies (permitting the booster to continue launch with one engine out). A reduction in thrust to 415,000 lb. is being considered as a result of Grumman Aerospace Corporation's Phase A shuttle study which shows that the now favoured drop tank concept is best with lower thrust engines.

The thrust level of the SSME will not be the greatest of any LOX/LH₂ engine (the cancelled M-1 developed one million lb. thrust, although only the powerhead was ever tested), but its life expectancy is the most demanding: a total run time of 7.5 hours spread over 100 missions, with a minimum capability of 6 runs at emergency power. Turn-around time will be 2 weeks with only visual inspection and onboard computer checks. To determine reusability requirements, Rocketdyne tested a standard J-2 engine (Saturn V 2nd and 3rd stages) for a total of 20,002 sec. (compared to 270,000 for the SSME) and 103 starts. Normal J-2 run time is under 600 sec. with 3 starts. Only a propellant utilisation valve was changed during the test (to provide data on a new design). The 230,000 lb. thrust and the Isp were not degraded during the test and post test teardown showed no significant degradation of parts.

Rocketdyne initially proposed an 'aerospike' engine concept for the SSME, but this was rejected by NASA. All 3 competitors finally selected moveable bell designs. Early emphasis was placed on minimising costs and, thereby, keeping SSME performance as close to baseline as possible. This eliminated several 'nice to have' features such as a deep throttling capability (20:1) that would have increased mission flexibility. The 3 corporations conducted parallel studies under identical 6.6 million dollar Phase B definition

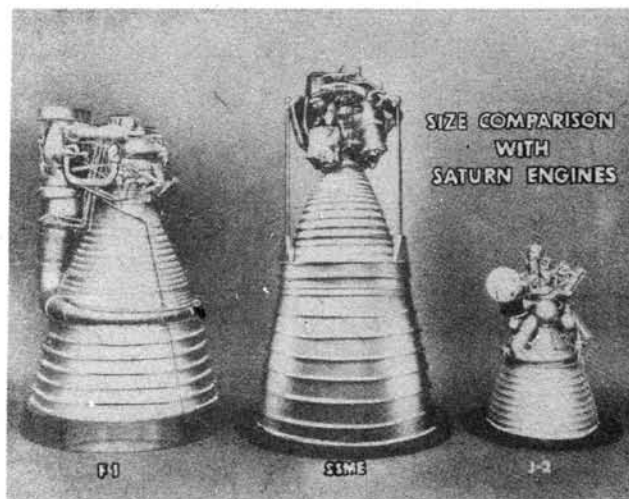
contracts. Final proposals were in by 21 Apr. 1971 for NASA evaluation. In early March, NASA selected the Mississippi Test Facility as the sea level test site for the SSME. The Saturn 2nd stage stands there will be modified for tests that will run from 1973 - 1979. The U.S. Air Force's Arnold Engineering Development Center, in Tullahoma, Tennessee, will be used for simulated altitude tests from 1974 - 1976.

The orbiter SSME will be 23 ft. tall with the nozzle extended, 12 ft. in diameter, and weigh 8500 lb. To maximize efficiency, Rocketdyne chose a staged combustion cycle with separate preburners driving the LOX and LH₂ pumps. For each, a low pressure turbopump delivers the liquid to a 2 stage, high pressure (5,940 psia, LH₂, 5,833 lb. LOX) turbopump. In the hydrogen turbopump, LH₂ is pumped through to the engine's regenerative cooling jacket. Part of the LH₂ then goes directly into the 2 preburners at a 1:1 (LOX:LH₂) ratio. This preburning drives the turbines for the oxygen and hydrogen pumps. The remaining LH₂ drives the LH₂ low pressure pump and then cools the preburners before being injected into them.

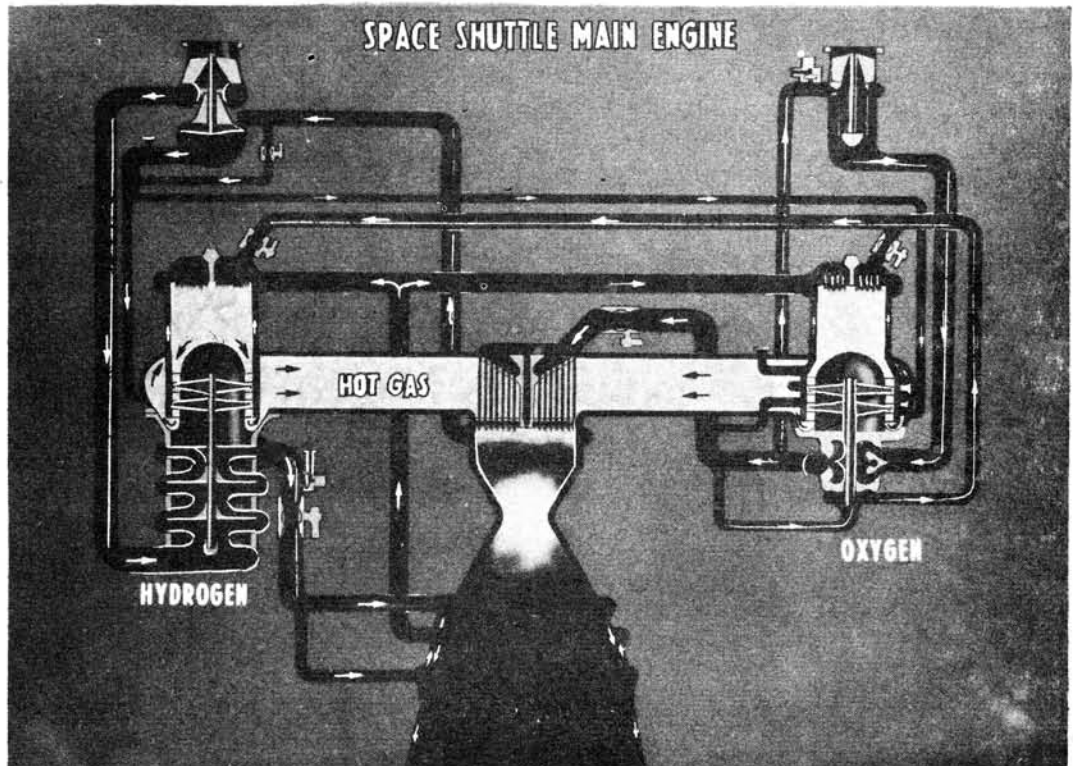
Similarly, the LOX is delivered to the preburners via a low pressure turbopump driven by LOX fed back from the main pump. Part of the LOX goes directly into the preburner and part directly into the main combustion chamber. There it burns with fuel-rich gases from preburners and produces a main chamber pressure of 3,000 psia. Temperatures in the copper-silver alloy (a proprietary alloy developed by Rocketdyne) chamber and nozzle are maintained around 1,000 °F, although 6,000 °F is reached within the chamber itself. Regenerative cooling carries away the heat load of 70 Btu/in.²/sec. Thrust control is achieved by regulating the return flow of propellants to their respective low pressure pumps. Normal mixture ratio, in terms of overall combustion, is 6.0:1, with thrust to be constant over a 5.5:1 to 6.5:1 excursion range.

Fig. 3. SSME compared with Saturn V engines. The F-1 is used in the first stage of the Saturn V, the J-2 in the second and third stages. NASA is currently studying the use of the SSME in a chemical inter-orbit stage pending the introduction of a nuclear stage.

All illustrations North American Rockwell (Rocketdyne).



Propellant flow diagram of space shuttle main engine.



The required 98.5% combustion efficiency level is achieved by dumping the turbo-pump gas products into the main combustion chamber rather than venting them as is done on other engines. The separate preburners also make possible the wide throttling and mixture ratios.

For maintenance, each turbopump/preburner combination will be removeable without dismounting the entire engine. Among the long life items that will be most difficult to develop, and which cause the SSME to be the pacing item in overall shuttle development, are pump seals and valves. These must take into account the pure oxygen and pure hydrogen environments that they will be operating in for extended periods, both at high pressures and speeds.

Also being taken into design consideration is the noise that the SSME is expected to generate. Up to 207 decibels of acoustic power are expected at the base of the shuttle booster. This is slightly higher than the noise generated by the Saturn V (although that vehicle produces more thrust and is bigger) because the SSME exhaust velocity is higher than the F-1.

Three subcontractors assisted Rocketdyne in development of the SSME: Honeywell, Inc. (control), Hydraulic Research and Manufacturing Co. (hydraulics), and Trans World Airlines (maintenance). Yet to be fully defined or contracted (although study contracts are out) are the orbital manoeuvring system (OMS), attitude control propulsion system (ACPS), and air breathing cruise engine (ABES). OMS thrust will be around 15,000 lb. and 2 shuttle study contractors are using Pratt and Whitney's RL-10 engine (Centaur) in their designs. ACPS thrust will be around 1,000 - 2,000 lb. and both ACPS and OMS will burn gaseous propellents stored in accumulators drawing from the main propellant tanks. The ABES are expected to be off-the-shelf jet engines now in use or soon

to be operational. A contractor for the shuttle itself is expected to be selected early in 1972.

The author wishes to thank F. L. Thistle, Public Relations Dept of the Rocketdyne Division of North American Rockwell, for information and illustrations used in this article.

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SPACE AND AGRICULTURE

World scientists meeting at the Rome headquarters of the Food and Agriculture Organisation (FAO) have recommended the creation of a Remote Sensing Development Unit within FAO to probe methods for exploiting the technique for the benefit of world agriculture. A report advises the Organisation to begin an examination of all its programmes and field projects to determine how remote sensing — carried out from air and space — could assist them. The techniques offer such disparate accomplishments as exact identification of areas of plant disease, the tracing of the course of marine pollution and even discovery of illegal plantations of marijuana.

The Earth Resources Technology Satellite (ERTS) to be launched in March by NASA will be programmed to carry out no fewer than 1,000 remote sensing operations, about a third of these requested of the Space Agency by 30 nations and international organisations, including the FAO.

The success due to recent technological advances in remote sensing clearly indicates that FAO and its member countries, particularly the developing nations, cannot ignore using these techniques, the report states. Because of FAO's commitment to the global problem of food production, agricultural and forest productivity, and fisheries development, it is essential that the Organisation avail itself of the vast quantity of data from both airborne and satellite systems which are shortly to become available.

Remote sensing is a development of basic aerial photography. In the past 10 years, largely as a result of space technology, a variety of Earth sensing instruments such as multispectral scanners, radar, high resolution optics and films — in particular infrared colour films — have been developed. With these devices it is now possible to examine natural resources on vast scales to exacting measures and rapidly. The economics of the new techniques are often particularly suited to the problems of developing countries.

Some of the most impressive presentations were made by scientists from Brazil, Mexico and India. High quality colour photographs of their forests, crop land and marine developments demonstrated the degree to which they have begun to make practical use of remote sensing from helicopters and small aircraft mounting economical 35 mm and 70 mm photographic equipment.

Infrared aerial photographs of Brazilian coffee plantations clearly revealed areas infected with coffee rust disease, which showed up white against red. Conventional ground methods of locating such plant diseases are expensive and take many months. With a small aircraft vast areas were photographed in a few hours. Processing and interpretation of the photographs took only a few days.

'You can imagine the economic and social importance of this,' said Dr. Fernando De Mendoca, Director of the Institute for Space Research in Sao Paulo, 'when you consider that 27% of Brazil's foreign earnings come from coffee.'

Mr. Fernando Garcia Simon, of the Mexican Secretariat for Water Resources, showed photographs that clearly located sewage-pollution and the resultant heavy growth of algae in the Salto River flowing out of Mexico City. Diseased field crops and trees in forests showed up in brightly contrasting colours on infrared aerofilm but were otherwise invisible to the eye. He said that the Mexican government is also beginning to use aerial remote sensing to locate marijuana plantations as well as to check on farmers who falsely claim they are fertilising their lands with inputs provided

by the government.

Professor P.R. Pisharoty, of the Physical Research Laboratory, Navrangpura, Ahmedabad, India, said that the United Nations, FAO and other appropriate international organisations, should serve as the link between developing countries desiring to acquire the new technology, and developed countries willing to help them acquire it.

The meeting also discussed the scheduled launching in March by NASA of an Earth Resources Technology Satellite (ERTS-A), followed by a second ERTS and a manned Skylab in 1973. They will be the first satellites designed specifically and exclusively for detailed examinations of the organosphere, the approximately 900-ft. layers of air, land and sea of the Earth's surface which constitute the principal zone of biological productivity.

Scientists and officials at the Technical Consultation to FAO on Remote Sensing, in addition to Brazil, Mexico and India, came from the U.S., Canada, Italy, France, the UN Outer Space Affairs Division, the European Space Research Organisation (ESRO), UNESCO and the FAO itself.

CORN BLIGHT DETECTED

A joint experiment conducted by NASA and the U.S. Department of Agriculture (USDA) to gather information on southern corn leaf blight from aircraft was completed late last year. Preliminary results show the blight can be detected and its progress monitored by sensor-bearing aircraft.

Although southern corn leaf blight was not as severe as expected in 1971, the presence of such a widespread infestation provides a unique opportunity to assess remote sensing for largescale crop surveys.

Colour infra-red photography from a U.S. Air Force RB-57F aircraft and multi-spectral electronic data recorded by a University of Michigan C-47 aircraft, both under contract to the MSC, were used in the experiment to determine how well crop diseases such as corn leaf blight can be detected from high-flying aircraft or spacecraft.

The RB-57 collected colour infra-red photography of more than 72,000 square kilometers (45,000 square miles) of America's richest corn country in the states of Ohio, Illinois, Iowa, Indiana, Missouri, Michigan and Nebraska during the corn growing season from June to September. This photography was supplemented by electronic data collected by the C-47 covering about 6,720 square kilometers (4,200 square miles) in an intensive study area in Indiana.

During the 4 month study, the aerial information was compared periodically with data collected on the ground in a group of sample fields which had been selected in advance for detailed study and observation. Personnel from federal and state agricultural agencies responsible for the ground watch phase of the programme made plant-by-plant inspections of corn on these sites at intervals of about 2 weeks.

Simultaneously with ground studies, the same areas were photographed from the RB-57 flying at an altitude of about 60,000 ft. These photographs, together with ground study data, were then sent to a photo-interpretation team at Purdue University's Laboratory for Application of Remote Sensing, Lafayette, Indiana. This team analyzed the photographs and compared results with those obtained by state and federal agricultural field personnel to determine the effectiveness of using remote sensing from high altitude

aircraft to monitor the development and spread of corn blight, assess the levels of infection, and determine the probable impact of the blight on crop production.

The results showed not only that corn blight could be detected and its progress tracked from high-flying aircraft, but analysis of infrared photography taken by the RB-57 indicated three levels of infestation beginning with the early to middle phase.

'KOSMONAUT YURI GAGARIN'

The new Soviet space research and tracking ship '*Kosmonaut Yuri Gagarin*' (*Spaceflight* December 1971 p.463) last autumn completed 17 days of trials in the Baltic in fog, rain and rough weather. The ship is said to be the most comprehensively-equipped of its kind afloat, fully automated with over 120 laboratories. Apart from communicating with unmanned satellites and manned spacecraft in Earth-orbit, it can remain in contact with spacecraft en-route to the Moon and Mars 'or functioning on those planets'. While operating it is constantly in touch with the command centre in the Soviet Union.

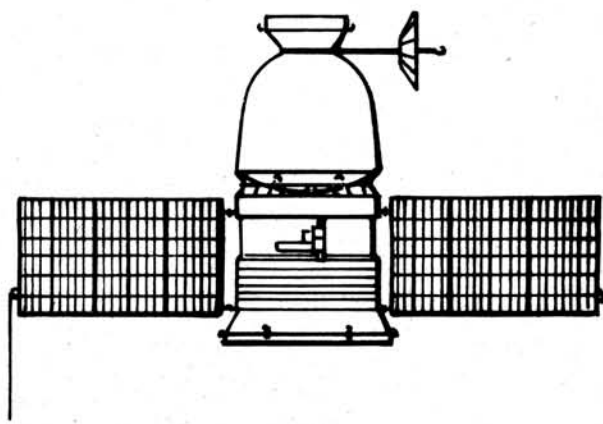
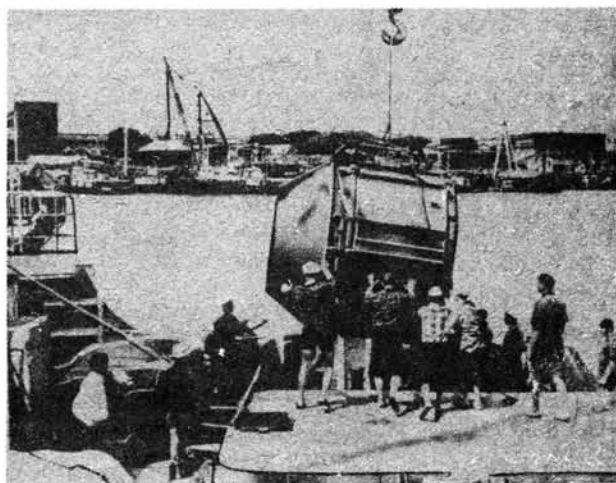
According to *Novosti*, the ship need not fear obsolescence. It is packed from floor to ceiling with the most advanced radio telemetric, navigational, electrical and computing equipment. There are several computers and thousands of rack-mounted equipment modules. Many of these modules are duplicated. If one fails another takes over. All systems have automatic fault-finding circuits and failed elements are replaced through switchgear. As more advanced equipment is developed it can be plugged into the system merely by replacing appropriate modules.

Crew and members of the expedition — physicists, astronomers, mathematicians, engineers and technicians — have been provided with the maximum of amenities. The ship has an automatic telephone exchange, an amphitheatre for films and lectures seating nearly 300, rest rooms, 3 swimming pools (one heated), and a large gym.

Contact with the Soviet Union when on Atlantic or Pacific station probably depends on Molniya communications satellites, writes Kenneth Gatland. It also seems likely that the vessel obtains its all-weather navigational 'fix' from Soviet navigational satellites of the Cosmos series.

ANIMALS AROUND THE MOON

Experimental results obtained by Soviet scientists from 4 Zond spacecraft sent on circumlunar trajectories between September 1968 and October 1970 have now been fully analysed. The spacecraft, launched by Proton boosters, closely resembled the Soyuz spacecraft without the attached spherical instrument module. A sketch from a Soviet source appears above. It is believed the ultimate objective of this programme was to man-rate the Proton launcher for circumlunar flight, writes Kenneth Gatland.



Re-entry capsule of Zond 5, concealed within a container, is taken from the recovery ship *Vasily Golovnin* in Bombay Dockyard before being flown back to the Baikonur cosmodrome. *Below*, flight configuration of Zond 5 reconstructed from a Soviet source.

Photograph *Novosti* Press Agency; drawing by William Hobson.

The vehicles carried a range of test subjects including tortoises, drosophila, onions, seeds of wheat and barley, chlorella strains and intestinal bacilli.

Total dosage of space radiation, recorded at different points, was about the same on all flights.

After return to Earth the tortoises were active; they moved a great deal and had good appetites. During the experiments they lost about 10% of their weight.

Blood tests (numbers of leukocytes, erythrocytes and haemoglobin) and electrocardiographs revealed no essential differences from those of control animals.

Morphological and histochemical analyses of a number of organs and tissues of tortoises which had been on the Zond-5 flight revealed several changes in the content of glycogen

and iron in the liver and structural changes in the spleen. Subsequent experiments, however, failed to confirm these findings.

The flights stimulated the growth and development of the seeds of wheat, barley and onions and the appearance of certain chromosome disturbances in these specimens. Both qualitatively and quantitatively these changes, in the majority of cases, did not differ from the changes recorded in experiments conducted in near-Earth orbits.

The flight conditions gave rise to a comparatively large increase in the number of chromosome changes in the seeds of pine and barley, and a rise in the mutants of *Chlorella* strains, the scientists reported.

ACTIVITY AT ESRANGE

Following an extremely busy period at the European Space Research Organisation's sounding rocket range early in 1971 (*Spaceflight*, Oct. 1970, p.385), the ensuing months were fairly quiet, primarily because of the annual closure of the Kiruna range between 15 Jun. 1971 and the end of July. Activity was resumed on 31 July when a French Centaure rocket was launched at 0120 CET carrying an experiment designed by the Institute of Meteorology, Stockholm, to measure occurrences and properties of aerosols in the mesopause in studies of processes leading to noctilucent cloud formation. High-quality telemetry was received from the payload for over 6 minutes as the instruments reached the peak of the trajectory and initial indications are that the payload functioned correctly, writes Geoffrey Falworth. At 0109 on 1 Aug, a second Centaure carrying an identical payload, designated C59, was launched from Kiruna and it too performed as planned.

During the summer months launchings of ESRO-sponsored sounding rockets took place at the Italian launch site of Salto di Quirra in Sardinia. A Skylark rocket, launched at 1155 CET on 2 July, carried payload S73 consisting of experiment R-214 being a set of photometers from the Landes Sternwarte, Heidelberg, to measure zodiacal light in the direction of the Sun, and experiment R-301, an X-ray spectrometer from the Paris Observatory. Skylark reached an apogee of 224 km and as the payload section slowly rotated, as required by the zodiacal light experiment, the X-ray spectrometer remained pointed at the solar disc for 5 min. 3 sec. All onboard systems worked extremely well and the zodiacal light experiment produced a vast amount of data; the objectives of that experiment were to measure the intensity and polarisation of the zodiacal light which would enable values for the spatial distribution, density, particle size and composition of interplanetary dust to be obtained which, in turn, will help to explain the origin and dynamics of the zodiacal light. The Paris Observatory experiment acquired detailed monochromatic images of the solar disc in selected X-ray emission lines between 7 and 10 Å in studies of densities and temperatures of the solar corona above active regions, three of which were present on the Sun during the Skylark launch.

A mass spectrometer from Berne University, a micrometeoroidal flux measurement device from Lund Observatory and a parachute package and ion density experiment from ESRO's European Centre for Space Research and Technology (ESTEC) Space Science Department at Noordwijk, Netherlands, formed Z82/1 launched from Sardinia on 30 Jul. 1971.

Telemetry was only received from the ESTEC experiment, however, preliminary investigations indicating a faulty separation of the booster and first stage rocket and premature ejection of the fairing. ESRO engineers were investigating the malfunction.

PRECISE SKYLARK

A one-minute 'window', which would not reappear for another 17 years, was successfully entered on 24 Oct. by a Skylark sounding rocket launched from Woomera, Australia, by a British Aircraft Corporation team. The rocket carried a payload, devised by the Mullard Space Science Laboratory (University College, London), to measure the position of an X-ray source close to the centre of our galaxy, to an accuracy of less than 2 secs. of arc. The rocket had to fly with great accuracy to the right altitude and geographical location to enable the experiment to observe the X-ray source — named GX3+1 — at the precise instant it was eclipsed by the Moon. The launch opportunity lasted only 1 min. and GX3+1 is next eclipsed over Australia by the Moon in 1988.

This was the second occasion within a month that such a launching had been undertaken by the BAC team. The previous experiment, also by a Skylark rocket, carried a similar X-ray counter devised, in this case, by Dr. K. Pounds of Leicester University. It was launched on 27 Sept. from Woomera.

The 24 Oct. launching should allow experimenters to plot a second line intersecting the first and thus to pin point more accurately than ever before this X-ray source.

MAJOR SOVIET 'SKY WATCH' PROJECT

More details are now available of the huge Rata-600 radio-telescope which Soviet engineers are just completing. The site is some 7,000 ft. above sea level in the northern spurs of the Caucasian range of mountains near the village of Zelenchukskaya, Strevopol Territory. After building a huge circular wall-like foundation, (*Spaceflight*, Jan. 1972, p.18) engineers began installing a 600 metres (1,968 ft.) diameter reflector supported by a ring of pylons.

Director of the Ratan-600 will be the veteran astrophysicist Dr. Y. N. Pariisky who attended the recent Soviet-American Conference on Communication with Extra-Terrestrial Intelligence (CETI) in Soviet Armenia (*Spaceflight*, Dec. 1971, p. 464 and Jan. 1972, pp.17-19). Pariisky 'signed in' under the title: 'Special Astrophysical Observatory, Soviet Academy of Science, Leningrad'.

The Ratan-600, apart from being used for advanced investigations into stars and galaxies, etc., is also to be used for long-distance space communications.

Another point of interest is that the new radio-telescope will operate synchronously with the world's biggest optical telescope which has been built on Mt. Semirodniki nearby. The Zelenchuk Astrophysical Observatory, which contains the 860-ton instrument with a 6 metre mirror, will exceed the capability of the 200-in. Hale reflector on Mt. Palomar.

The new Soviet reflector will collect nearly one-and-a-half times more light from space than the 200-in. The instrument is stated to be capable of discriminating 2 matches burning

20 metres apart at a distance of 10,000 km.

The 42-ton, 6-metre (28 m²) parabolic mirror, made in Moscow, received its final polishing in Leningrad. Permitted error of manufacture was no more than 4 hundredths of a micron.

The unique combination of the Ratan 600 and 6 metre reflector will be used to investigate a wide range of objects, from stars in the local Galaxy to pulsars, quasars and distant galaxies.

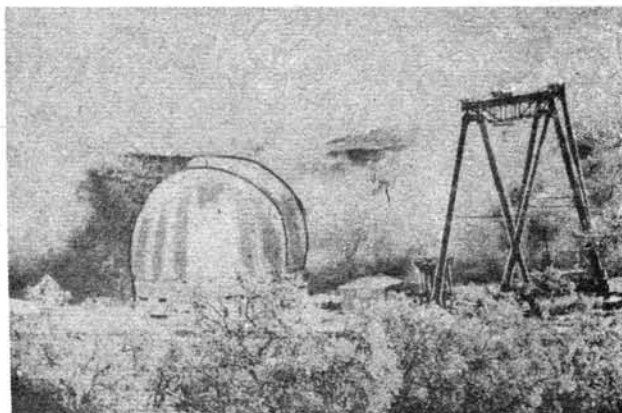
The 2 instruments are also likely to be used in CETI investigations. They will allow simultaneous observation of the same object over a wide spectral range. There may well be some work on possible planetary companions of nearby stars such as Barnard's Star, Lalande 21185A and 61 Cygni.

According to Sergei Rublev, the new telescope will make it possible to detect very weak celestial objects that have so far been inaccessible. Three main departments of the Observatory have been established: (1) Extra-galactic astronomy and cosmology; (2) stellar and interstellar media, and (3) planetary physics.

It is possible, says Rublev, 'that our new telescope will enable us to obtain data that will throw light on the nature of the Red Shift, on the expansion of the Universe and the geometry of the Cosmos. It holds great promise for investigating of objects at the fringe of the observable Universe. Test observations are due to begin this year.

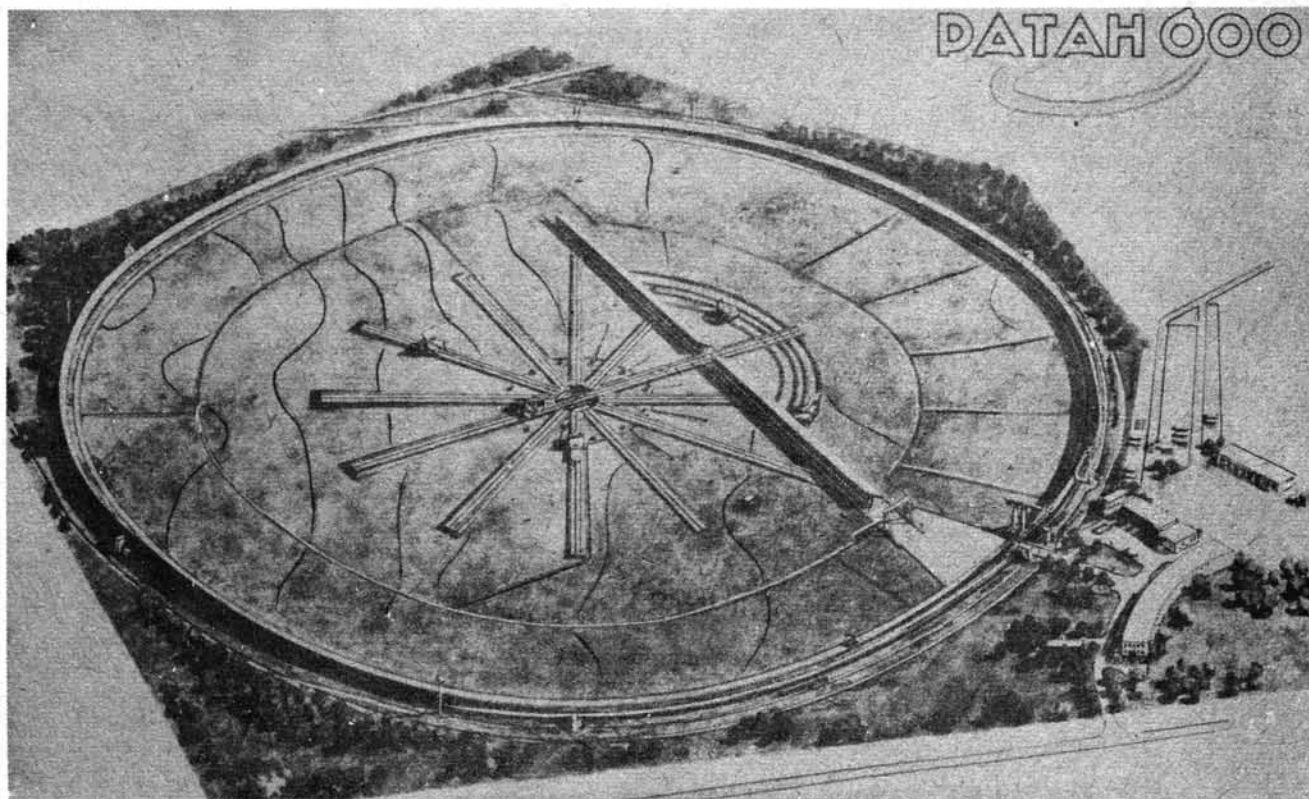
The Ratan 600 radio-telescope is nearly twice the size of the 1,000 ft. non-steerable dish at Arecibo, Puerto Rico. This American radio-telescope, designed by Cornell University, was built at a cost of \$8 million in a natural bowl formed by several mountain peaks. After the ground was sculptured into the shape of a paraboloid, a wire-mesh reflector made of

separate panels was set in place. The designers gave the instrument a degree of control by installing an antenna focussing device about 500 ft. above the reflector. There are 3 supporting towers. Attached to a 550-ton superstructure suspended on cables, the focussing device — also known as a 'line feed' — can be moved along the cables to cover a wide area of the sky.



Above, the Zelenchuk Astrophysical Observatory on Mt. Semirod-niki in the Northern Caucasus which now contains the world's biggest — 6 metre — optical telescope; below, first picture to show the configuration of the 600 metre Ratan-600 radio-telescope which Soviet engineers are building in the same area.

Novosti Press Agency, and 'Special Astrophysical Observatory', Leningrad.



SATELLITE DIGEST – 43

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see February 1969 issue, page 66.

Continued from January issue, p. 31.

Name and designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and origin
Cosmos 432 1971-66A	1971 Aug 5.42 12.91 days (R) 1971 Aug 18.33	Sphere-cylinder 4000?	5 long? 2.44 dia	194	259	51.74	88.97	Tyuratam-Baikonur USSR
1971-66D	1971 Aug 5.42 16 days 1971 Aug 21	Sphere?	2 dia?	187	231	51.7	88.6	Tyuratam-Baikonur USSR (1)
1971-67A	1971 Aug 7.01 21.99 days 1971 Aug 29.00	Cylinder 70?	2.05 long? 0.72 dia?	133	1970	92.01	106.29	WTR Atlas F USAF
1971-67B	1971 Aug 7.01 80 years	Cone-cylinder + boom 70?	2.05 long 0.72 dia	790	970	87.63	101.92	WTR Atlas F USAF
1971-67C	1971 Aug 7.01	Sphere 400?	0.66 dia	133	1957	92.00	106.16	WTR Atlas F USAF
1971-67D	1971 Aug 7.01	Sphere 61	0.30 dia	137	884	87.61	94.87	WTR Atlas F USAF
1971-67E	1971 Aug 7.01 15 years	Spherical frame 6.2	2.13 dia	777	914	87.61	101.86	WTR Atlas F USAF
1971-67F	1971 Aug 7.01 15 years	Spherical frame 4.0	2.13 dia	792	914	87.64	102.01	WTR Atlas F USAF
1971-67G	1971 Aug 7.01 6 months	Inflated sphere 0.8	2.13 dia	795	913	87.62	102.03	WTR Atlas F USAF
1971-67H	1971 Aug 7.01 15 years	Sphere 1.6	0.61 dia	790	914	87.64	101.99	WTR Atlas F USAF
1971-67J	1971 Aug 7.01 20 years	Sphere 34?	1.12 dia	794	907	87.62	101.96	WTR Atlas F USAF
Cosmos 433 1971-68A	1971 Aug 8.99 0.06 day (R) 1971 Aug 9.05	Tapered cylinder 250	2 long? 1 dia?	112	299	49.4	88.6	Tyuratam-Baikonur USSR (2)
Cosmos 434 1971-69A	1971 Aug 12.23 5 years	Irregular cylinder	6 long? 3 dia?	188 189 186	267 1328 11804	51.60 51.60 51.60	88.98 99.90 228.24	Tyuratam-Baikonur USSR (3)
1971-70A	1971 Aug 12.59 22 days 1971 Sep 3	Cylinder 3000?	11.25 long 1.52 dia	137 136	424 410	111.00 110.96	90.13 89.98	WTR SLC 4-West Titan 3B Agena D USAF (4)
Eole 1 1971-71A	1971 Aug 16.78 80 years	Octagon + cone + 8 panels + boom 84.37	0.58 long 0.71 dia	677	904	50.16	100.62	Wallops Station Launch Area 3A Scout B France (5)
Cosmos 435 1971-72A	1971 Aug 27.46 5 months	Ellipsoid? 400?	1.8 long? 1.2 dia?	271	482	70.96	92.09	Plesetsk Cosmos USSR

Supplementary Notes:

- (1) Capsule ejected from Cosmos 432. Orbital data supplied by NORAD.
- (2) Re-entry capsule ejected during first orbit.
- (3) Orbital data at 1971 Aug 12.9, Aug 16.4 and Aug 27.3.
- (4) Orbital data at 1971 Aug 13.2 and Aug 30.2.
- (5) CAS A, second French experimental meteorological satellite and first launched by NASA under a co-operative agreement with Centre Nationale d'Etudes Spatiales acquires telemetered data on upper atmospheric wind velocities, wind directions, temperature and pressures from instrumented Earth-circling meteorological balloons, demonstrates satellite and balloon technology and electronics systems and capability to acquire range and range-rate data in determinations of balloon locations from Earth orbit, provides data for Earth's atmospheric circulation studies, bases for standard atmospheric pressure and temperature reference system in support of World Weather Program and investigations of localised stratospheric wind phenomena, and studies feasibility of a modified onboard Doppler system which, when combined with satellite-acquired range measurements, locates horizontal positions of balloons to within ± 3 km. Power of 20 watts average is supplied by eight rectangular solar panels deployed 45° from Eole 1's upper octagonal structure after orbital insertion and a rechargeable silver cadmium battery pack. Constant Earth-orientation is maintained by a deployable 10.06-metres long gravity gradient boom. Onboard telemetry system uses 2 pulse code modulation/pulse modulation transmitters, one operating at 464.4864 MHz at 4 watts transmitting through a 4-arm conical spiral experiment antenna mounted on Eole 1's base interrogating Earth-circling

meteorological balloons and the other operating at 136.350 MHz at 250 mw transmitting telemetry and re-transmitting balloon-originating telemetry to ground stations through an Earth-pointing canted turnstile telemetry and command antenna, the latter also being utilised for initial orbital tracking by NASA's Space Tracking and Data Acquisition Network stations and subsequently by CNES stations. Command receiver, operating at 148.25 MHz using standard Goddard SFC tone digital command system, uses 2 address codes, one for standard spacecraft commands and both for telemetry programming of balloon operations. During nominal required 180 days' active lifetime Eole 1 interrogates up to 750 helium-filled, 30-days lifetime, 3.66-metres diameter meteorological balloons launched at the rate of 3 per day or 125 every 2 weeks by CNES and Argentine personnel from Argentinian stations at Mendoza located at 33°S, Neuquen at 39°S and Lago Fagnano at 55°S. Each balloon carries a frangible 9.75 metres long instrumentation suspension line carrying instrumentation including temperature and pressure sensors, solar cells and batteries for power supplies, telemetry receiver operating at 464.4864 MHz and transmitter operating at 461.71796 MHz at 4 watts and is expected to circle Earth south of latitude 30°S. Eole 1 interrogates the balloons either individually, in sequence or in programmed groups of up to 64 balloons during nightside and dayside transits whilst balloons drifting beyond experiment limits of between latitudes 30°S and 60°S are destroyed on command from the spacecraft thus reducing unrequired data collection points. Eole 1 was the 7th French satellite to attain orbit, 2nd French satellite launch by NASA and first French satellite launch from Wallops Station; 58th Scout satellite launch and 47th successful Scout satellite mission was the first Scout B to use S-band telemetry.

BLUE STREAK IS VINDICATED

Analysis of telemetry records from the Europa 2 F.11 ELDO launcher which failed to achieve orbit from Kourou, French Guiana, on 5 Nov. 1971 shows that the 100% success rate of Blue Streak was maintained. It had been successful in all 10 previous launchings. After a troublefree countdown period the vehicle was launched at the scheduled time and performed perfectly until 105 seconds after launch.

According to Hawker Siddeley Dynamics, data analysis indicates that at T plus 105 sec, when the vehicle was at a height of about 17 miles (27.4 km), the inertial guidance system carried in the 3rd-stage ceased to function for reasons not yet known. At this point failure occurred. However, Blue Streak continued to function correctly, in the absence of a guidance signal, and the vehicle reached an incidence of 35 deg to the flight path. Blue Streak withstood the severe stresses resulting from this manoeuvre, but structural failure occurred at the junction of the first and second stages at T plus 150 seconds. As a result of this failure, Blue Streak pushed into the rear of the French 2nd-stage. Its upper propellant tank was punctured causing an explosion.

The upper stages then separated but an explosion in the 2nd-stage occurred at T plus 161 sec.

Detailed investigation is continuing into the problem with the inertial system which was being used operationally for the first time. The basic unit was flown as an experiment on Europa 1 F.9 at Woomera in 1970 but merely fed results to data recorders. On this occasion it was linked to autopilots in the first, second and third stages controlling the flight. On F.9 the system came fully up to expectations. Prime contractor and integrator of the system is Marconi Space and Defence Systems but components are manufactured in other ELDO countries as well as Britain.

It has still to be decided when the next launch (originally to be of the F.12 test vehicle in April) will take place.

At the ELDO Council Meeting in Paris on 18 November a review commission was set up, comprising representatives of all ELDO countries, including Britain, to analyse technical problems and contractors' management arrangements as possible contributory factors.

Results of the review commission should be reported by the end of January. It will then be decided if Europa 2 F.13 will have to be used as a second proving shot instead of being the first operational launcher for the Franco-German Symphonie communications satellite. This would add another £8 million to the programme cost.

THE SHUTTLE - AN ECONOMIC APPRAISAL

Continued from p. 54

context, several years of reduced project appropriations would serve to stimulate a more generous use of the system. Interest has been expressed for a modular space station and NASA has awarded definition study contracts to North American Rockwell and McDonnell Douglas which will be completed by December 1971. It is hoped that within a few years of shuttle operations the way will be clear for a series of flights to orbit, in order to dock several modules together to form a rudimentary 6-man space station. Alternatively, the capacious cargo bay of the shuttle could serve as a short-term Earth resources laboratory, a mount for astronomical telescopes, or continue research into materials processing in space.

It may well be too early to be optimistic over the shuttle's economic advantages. Unquestionably reusability offers the logical next step toward the development of cheaper and more practical use of space. However, the real asset may well lie in another direction. Industry can pursue the development of manned space vehicles, NASA can retain the nucleus of a manned space flight programme, and the existing facilities can be utilised in a practical way to marry the manned and unmanned programmes. This could bring returns unparalleled in modern technology.

EXTRAGALACTIC RADIO SOURCES

By M. P. Damon

Introduction

The general background radiation which is incident upon the Earth has its origin in both galactic and extragalactic regions, and for the continuous part of the spectrum, can be classified into thermal and non-thermal components. The first is simply a consequence of the fact that all bodies at a temperature above 0°K (Absolute Zero) emit energy in the form of electromagnetic radiation due to motion of charges at the surface of the body. As the degree of agitation of these charges is determined by the temperature, so the resulting emissions will be characteristic of the temperature. Generally, thermal emission is much weaker than non-thermal, but can be detected in emission above 20 MHz and in absorption at lower frequencies. The commonest thermal sources are large clouds of Hydrogen (HII regions) within our Galaxy. In these cases, energy is supplied by neighbouring hot O and B type stars.

In our discussion of extragalactic sources, however, we will find that non-thermal emissions play a more important part. When a charged particle is constrained to move in a regular manner, such as by the presence of a magnetic field, then the emission characteristics undergo considerable change.

The path of a non-relativistically moving charged particle, such as an electron, in a magnetic field is a helix around the lines of force, and its orbital frequency is dependent only on the magnetic field strength. This centrifugal acceleration subsequently gives rise to the emission of radiation known as cyclotron radiation and has a value of 2.8 MHz per gauss. Therefore, in Galactic regions where the magnetic field strength is approx 10^{-6} gauss, a slowly moving electron would radiate at 2.8 Hz.

There are, however, considerable quantities of high energy particles present in Galactic regions, most of which are generated in novae and supernovae explosions. In the presence of a magnetic field, these relativistic particles give rise to an extremely intense synchrotron radiation, decreasing in intensity from radio wavelengths through the visible portion and out as far as the X-ray region. We thus have at our disposal a reasonable explanation for the generation of background radiation and, as it turns out, it would also suggest the mode of emission in the so-called 'radio stars'.

In the ensuing discussion of radio objects, we shall be confining ourselves to descriptions of Normal external galaxies, Radio galaxies, and the last in the line of astronomical oddities, the quasi-stellar radio sources which, if anything, have aggravated the problem of determining how such vast quantities of energy can be emitted over such short periods.

Galactic Classification

External galaxies can be classified into 'weak' or 'strong' groups by plotting radiated power in the radio range against type of object, as shown in Fig. 1. A sharp division can be found at about 10^{41} ergs s^{-1} , those below being weak sources, those above being strong.

Another method is to express the objects radio spectrum by means of the term $S=f^{-\alpha}$ where α is the spectral index. In this way, sources of thermal origin can be distinguished from those which exhibit synchrotron emission. S is the flux density, and f the frequency.

Normal, or weak galaxies are difficult to observe as the objects invariably exhibit low surface brightness, often less than 1° . Long wave-length studies of M31 by Brown and

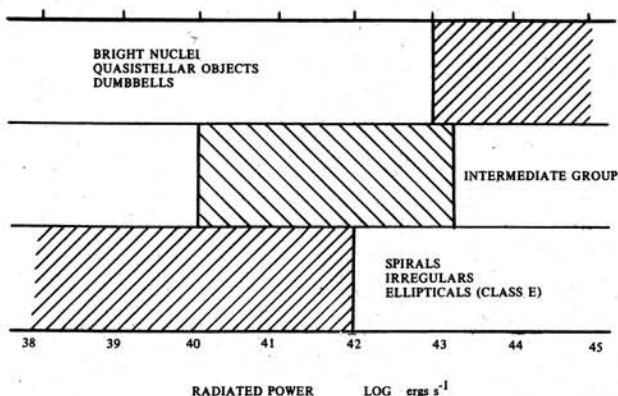


Fig. 1. Classification of radio sources.

Hazard have led to a model for emission from late type spirals, consisting of a 'disc' component with approximately equal dimensions as the optical galactic disc, and a 'halo' component of far greater spatial spread. Fig. 2 shows their results at 158 MHz. One can therefore assume that the birthplace of such radiation is at the heart of the Galaxy, where presumably the degree of turbulence is greatest.

The Radio Galaxies

As we have noted, radio galaxies are known for their characteristically stronger emission over the radio range, and at these frequencies they exhibit a double structure in that the emission centres are located in 2 regions placed symmetrically to either side of the galaxy concerned at distances of about 150 Kpc. (1 parsec = 3.26 light years = 2.06×10^5 astronomical units = 3.1×10^{13} km.) These components have similar spectral characteristics, so the intensity contours are fairly frequency independent. Figs. 3 to 6 show several examples of the structure of radio galaxies in which the optical and radio 'images' have been superimposed.

The foremost example of a radio galaxy is Cygnus A, which incidentally was the first discrete source to be discovered and which is the second brightest radio object outside the solar system. This source, identified by Baade and Minkowski, is a distorted nebula amongst a loose cluster of galaxies, and the 2 components are separated by $100''$ of arc (80 Kpc). Observations at 21 cm. show a faint emissive bridge connecting the 2 components.

The first observation led to a theory of emission for these external sources whereby 2 colliding galaxies converted some of their Kinetic Energy into electromagnetic radiation. For reasons considered later this collisional theory had to be discarded because of the difficulty in postulating such an efficient energy conversion process.

Fornax A (Fig. 6) and Centaurus A (Fig. 3) are both of sufficient angular extent to be resolvable by pencil beam aerials. The characteristic double structure is exhibited by both sources with the components extending more than 100 Kpc from the central cluster. In Centaurus A, there are also 2 bright components lying within the galaxy and separated by 8 Kpc. These are shown in the inset to Fig. 6.

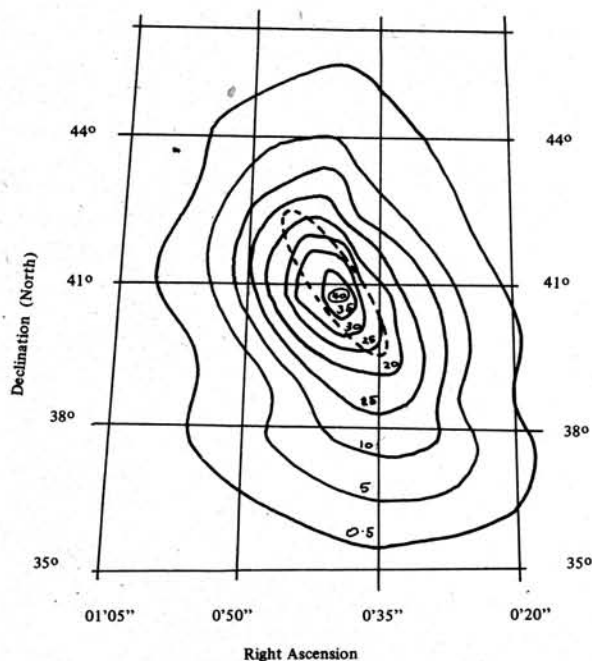


Fig. 2. Isophotes of M31 at 158 MHz with the background radiation removed. Contours are marked in arbitrary units of brightness temperature. The visible galaxy is shown by the dotted line.

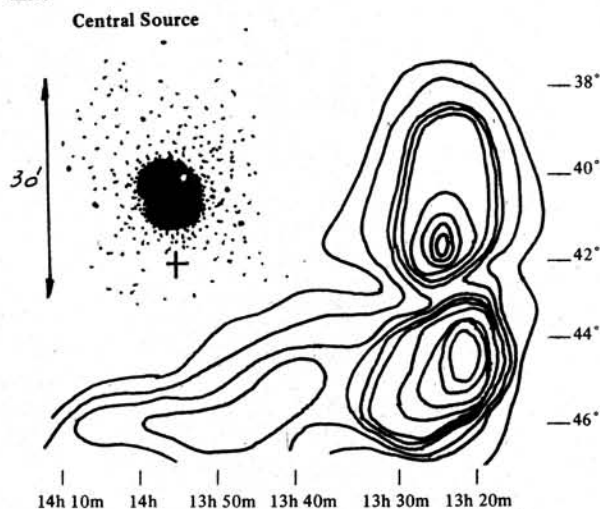


Fig. 3. The extended source and the central source (inset) in Centaurus A.

As a means of comparison between radio sources, Fig. 8 has been included. This shows the spectra of Hercules A (elliptical galaxy), IC443 (supernovae remnant), NGC 1275 (core and halo source), and 3C48 (quasar). The decrease in intensity at longer wavelengths in the case of quasars is caused by synchrotron self-absorption while that of double or elliptical galaxies, and also of supernovae remnants is probably caused by absorption in HII regions. Conversely the spectrum of core and halo sources exhibit an increase of flux density with increasing wavelength, and is caused by halo predominance where the contribution to the observed flux by the halo increases until at decametric wavelengths it predominates.

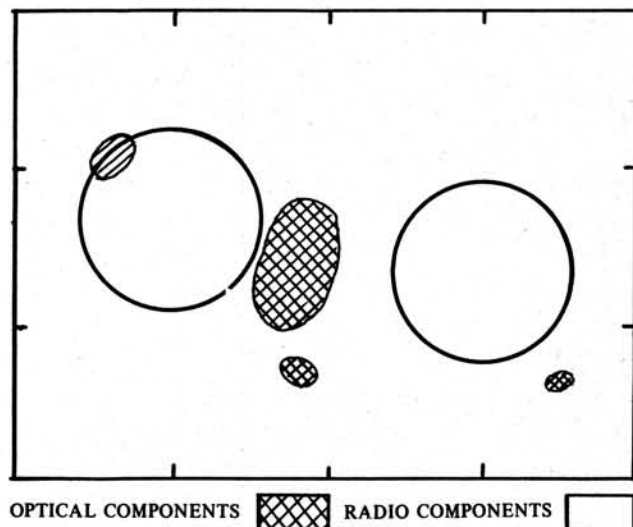


Fig. 4. 3C270. The central galaxy is NGC 4261 and scale graduations are 10 Kpc apart.

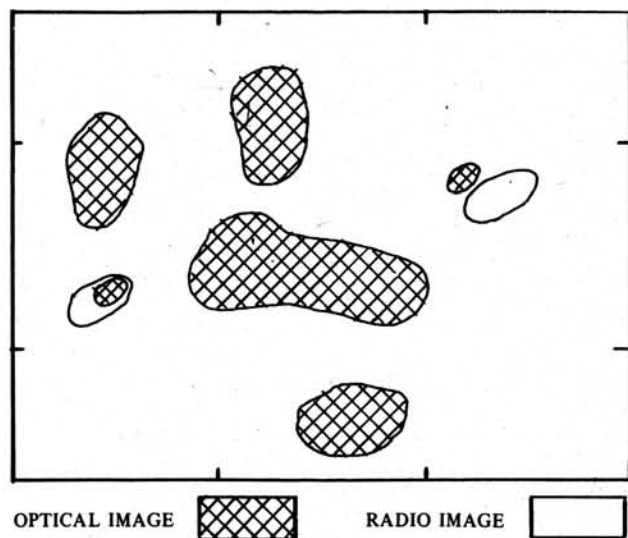


Fig. 5. Radio components of Cygnus A superimposed on the optical image. Scale graduations are 40 Kpc apart.

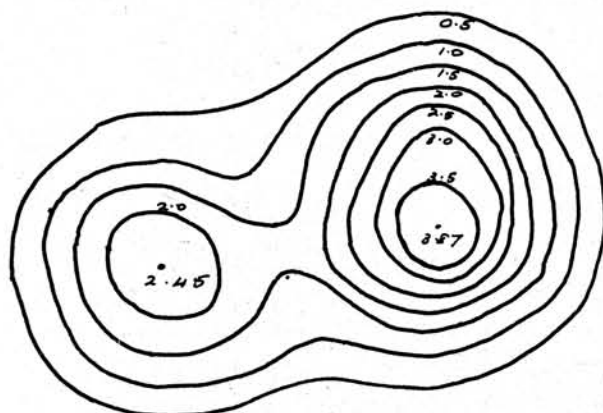


Fig. 6. Radio contours of Fornax A superimposed on an optical plate. The central galaxy is NGC 1316.

SOURCE	R.A.			DEC.		ANGULAR DIA.
	h	m	s	deg	min	
CYGNUS A	19	57	44	40	37.4	0.7 each
VIRGO A	12	28	17	12	39.9	0.6 core 6.5 halo
CENTAURUS A	13	22	36	-42	48.4	3.8 2.0

Fig. 7 - Positions and angular diameters of the brightest Radio sources.

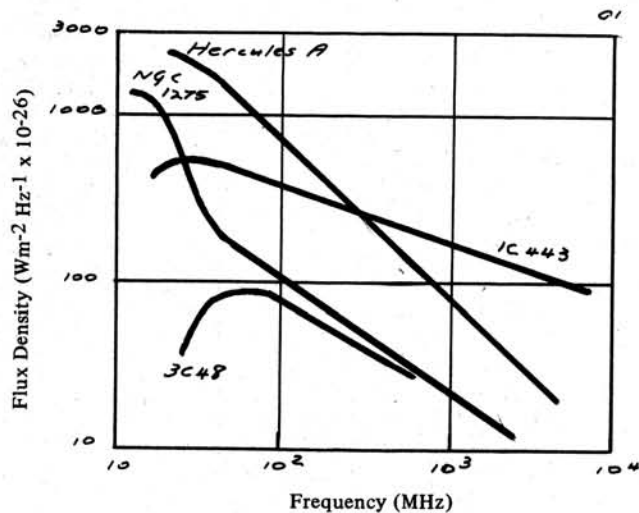


Fig. 8. Comparison spectra of various types of sources

A simple calculation will now show why the idea of colliding galaxies as a source of radio energy was finally discarded.

The radio spectrum of Cygnus A requires about 10^{59} ergs total energy output and this must arise from the K.E. of 2 colliding galaxies, mass $10^{10} m_{\odot}$ and $V(\text{rel})=10^3 \text{ Kms}^{-1}$, and where $m_{\odot}$ = mass of the Sun and equals $2 \times 10^{33} \text{ g}$.

$$\begin{aligned} KE_{\text{tot}} &= 10^{10} m_{\odot} \times 10^{16} \text{ ergs} \\ &= 2 \times 10^{59} \text{ ergs} \end{aligned}$$

Thus 50% of the available energy must be transformed into radio energy, and this necessitates an extremely efficient process. In general most radio sources appear to involve the collision of spiral galaxies and as spirals contain very little interstellar gas, so another difficulty arises over how the energy is dissipated and how synchrotron radiation is produced.

The collisional theory therefore had to be discarded and in its place came several new ones. These include:

1. Matter-antimatter annihilations in which electrons but no protons are produced. One disadvantage of this arises from the fact that the electrons produced are not highly energetic and therefore must be accelerated by another

process in order to produce synchrotron radiation.

2. Shklovsky's proposal that high supernova occurrence would account for a continual particle flux.
3. Burbidge's 'detonation' theory, by which one supernova explosion occurring in a densely populated region could trigger other similar explosions.
4. Hoyle's galactic 'flare' theory in which, assuming large angular momentum in the nuclear region of a galaxy, the magnetic field would be twisted up, followed by a discharge and a large particle flux.
5. Hoyle and Fowler's theory of gravitational collapse of a star of $10^5 - 10^8 m_{\odot}$, in which gravitational energy is converted into e.m. radiation.

Quasi Stellar Objects

Even until the 1960's, the objects now known as quasi stellar objects (quasars) were still thought to be ordinary faint stars within our own galaxy. In 1963 however the precise position of one of these radio emitters was found by the lunar occultation method (Hazard 1963) and subsequent optical searches associated this source with a faint starlike object. Schmidt then made a major breakthrough by identifying in the emission spectrum, lines due to the Balmer series of Hydrogen. As Fig. 10 shows, these lines have been displaced towards longer wavelengths in the normal red-shift manner.

Thus this quasar (3C273 - In the third Cambridge catalogue, the sources are numbered in order of increasing right ascension) was the first of a new series of cosmic objects having the following properties:-

1. Starlike objects associated with radio sources.
2. Variable light output.
3. Broad emission lines in the spectra.

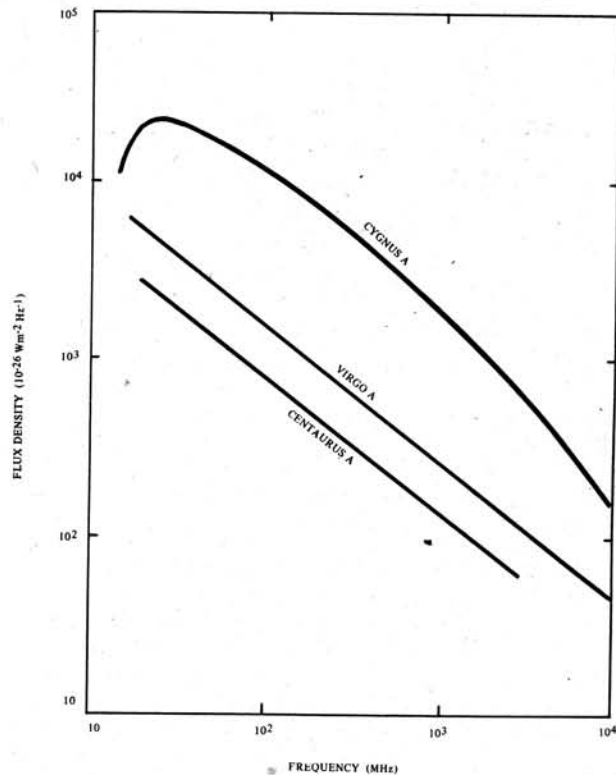


Fig. 9. Spectra of the three brightest sources.

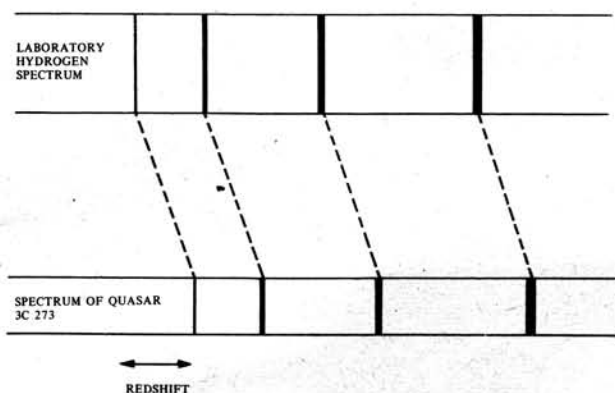


Fig. 10. The redshift of Quasar 3C 273.

4. Excess ultra-violet output.
5. Large red-shifts.

If the red-shifts are assumed to be due to the expansion of the Universe (as are the ordinary galaxies) then the quasars are extremely distant from us. Yet for the quasar to be detectable at these vast distances means that they must radiate, in the radio range, about $10^{43} - 10^{45}$ ergs s^{-1} , more than 100 times that of the normal galaxies!

If, however, quasars are localized objects, then their large velocities must have been caused by an explosion somewhere within our Galaxy, and it turns out that it is just as difficult to explain this vast output as it is to explain the energy requirements for distant objects. A further argument against the cosmological model is the fact that many quasars exhibit a variable output over times less than a year.

TABLE 1. Flux densities of some Quasars (S in flux units)
Subscripts refer to frequencies in MHz.

QSO	S ₂₆₅₀	S ₄₀₈	S _{85.5}	Spectral Index	Red-shift z
3C2	2.3	8.3	-	-0.7	1.037
3C9	1.2	6.6	-	-0.9	2.012
3C39	0.6	5.0	16	-1.1	-
3C57	2.0	6.5	14	-0.6	-
3C93	1.6	8.1	35	-0.9	-
3C94	1.5	9.9	25	-0.8	0.962
3C138	7.1	17.5	-	-0.4	0.760
3C175	1.3	8.6	-	-1.0	0.768
3C175.1	1.1	5.2	-	-0.9	-
3C181	1.1	6.3	-	-0.9	1.382
3C190	1.2	9.5	-	-1.0	-
3C191	0.8	7.7	-	-1.1	1.953
3C207	1.8	7.3	-	-0.7	0.684
3C215	0.9	4.6	-	-0.9	0.411
3C245	2.0	7.6	-	-0.7	1.029
3C273	37.3	55.1	167	-0.1	0.158
3C275.1	1.6	9.4	-	-0.9	0.557
3C279	-	15.0	37	-	0.539
3C298	2.7	24.4	-	-1.1	1.439
3C334	1.1	6.3	-	-0.9	0.555
3C432	0.7	8.0	-	-1.2	1.805
3C435	1.1	6.6	-	-0.9	-
3C446	4.4	10.6	30	-0.5	1.403
3C454	1.2	4.6	-	-0.8	1.757
3C454.3	10.0	15.8	-	-0.2	0.859

The size of the source must therefore be less than one light year in diameter, and this makes explanation even more difficult.

Conversely the fact that no blue shift is observed for quasars seems to indicate that the objects are not local since one would expect a component of the radial velocity to be towards us for at least a few sources.

Another hypothesis which has been put forward has been gravitational in nature, whereby the red-shifts are explained by the warping of spacetime (as by General Relativity) in the region of 'pockets' of hyperdense material such as a neutron star. This theory cannot, however, explain redshifts greater than 2, whereas the largest red-shift so far discovered has been $z=2.23$.

In short then, only more research on quasars, in particular on spectral widths and intensities, will resolve the problem.

Quasars as Radio Objects

It has been found that some radio sources identified as quasars have similar structures to those of radio galaxies in that they exhibit a double structure with large separations between components. Unlike radio galaxies, however, many quasars have an extremely small radio component.

From their radio spectra it is generally believed that the synchrotron method is responsible for the emission but if the objects are assumed to be local, then one may also explain this emission by a coherent plasma process. Difficulty arises, however, if one takes the indicated red-shift as being cosmological in origin for then emission by synchrotron processes leads to the relativistic particle energy exceeding the magnetic energy by large amounts.

Acknowledgements

The following are gratefully acknowledged:

1. Isophotes of M 31 at 158 MHz: Adapted from Brown and Hazard.
2. Contours of Fornax A: Adapted from a 10 cm study by Wade and a 48" plate by Zwicky.
3. Centaurus A: Adapted from papers by Bolton and Clark, and Maltby.

MARS FROM ORBIT — 1

Mariner 9: First Results

Within a week of Mariner 9 starting to photograph and probe the surface of Mars from orbit, scientists reported the following findings:

- (1) Mars has a large equatorial bulge — a surprise discovery.
- (2) The planet is 'gravitationally rough', exerting a strong gravitational field globally and locally. Local 'gravitational anomalies' may be caused by 'mascons', concentrations of dense material similar to lunar mascons lying beneath the Moon's maria or dry seas.
- (3) Water vapour, with its implications for life, is present in some abundance in the atmosphere over the South Polar Cap. This is the first measurement of water in the Martian atmosphere by a spacecraft, although in 1969 Earth-based studies detected water in the Martian atmosphere.
- (4) Mars is hot, but slightly cooler than recorded by previous U.S. Mariner probes in 1965 and 1969. The Martian daytime high is about 240 deg. Kelvin with the temperature peaking at mid-afternoon, not at noon. The nighttime high is about 200 deg. Kelvin.
- (5) The temperature of the Martian atmosphere is a constant 350 deg. Kelvin from near surface out to 40 km.
- (6) The great dust storm shrouding Mars was clearing, affording Mariner's twin TV cameras an opportunity to photograph craters and mountains and other interesting surface features. Neither the constituents of the storm nor its cause had been identified.

The findings were announced on 19 November by chief scientific investigators for the Mariner 9 project during a Press Conference at California's Jet Propulsion Laboratory

(JPL), control centre for the Mars mission.

Dr. Jack Lorell reported that Mars is bulged at the Equator but the specific site has not been pinpointed. Dr. Lorell, team leader of the celestial mechanics group trying to determine the shape of Mars from perturbations in the orbit of Mariner, said: 'We found Mars on a large scale rough gravitationally and on a small scale also rough. How rough we have not analysed yet'.

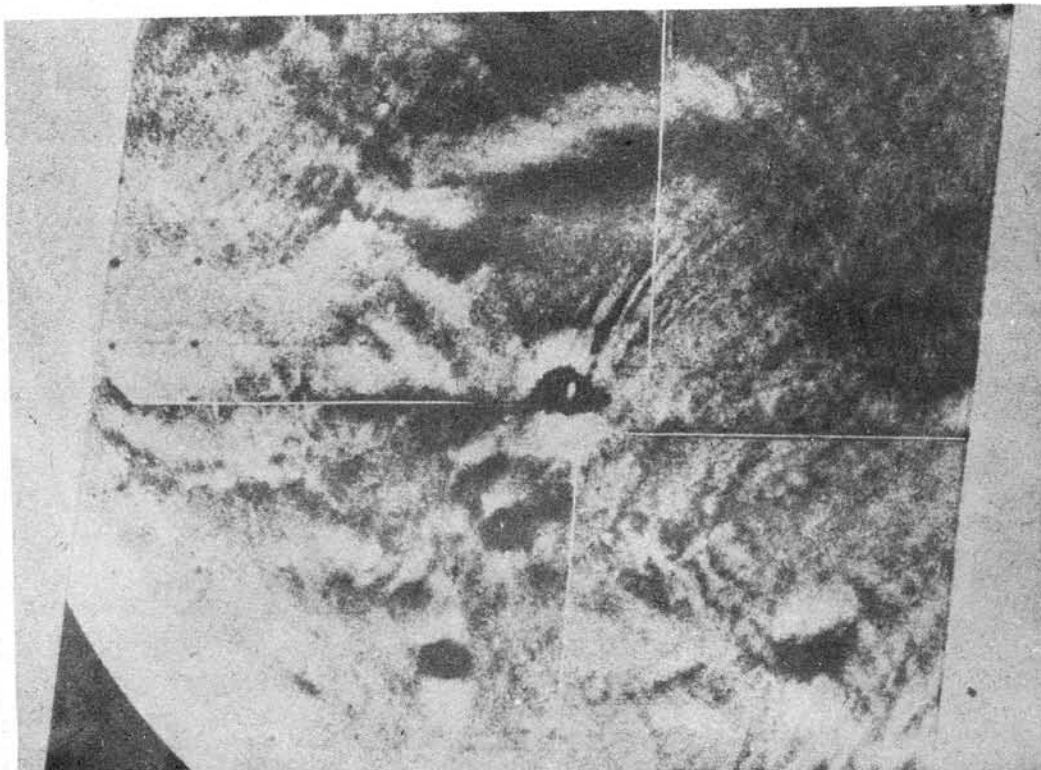
By 'rough' he meant gravitationally stronger than the Moon and Earth. Like all spinning planets, Mars is flattened at the Poles. One speaks of 2 axes for Earth, one North-South through the Poles and one East-West through the Equator. 'Mars is triaxial', Dr. Lorell said. The third axis is along a diagonal line North and South of the Equator to take into account the bulge in calculating the true shape, or geoid, of Mars.

The Martian bulge and smaller gravitational irregularities were discovered by noting tiny ups and downs in the orbital path of Mariner. The 'dips' were recorded as minute changes in the craft's velocity (2 or 3 mm per sec.), totalling about 5 sec. each revolution.

Dr. William O'Neill of JPL said the net effect is that Mariner slowed down 40 seconds in its first 8 revolutions but would regain this time as its orbital pass shifts away from the bulge and the suspected 'mascons'.

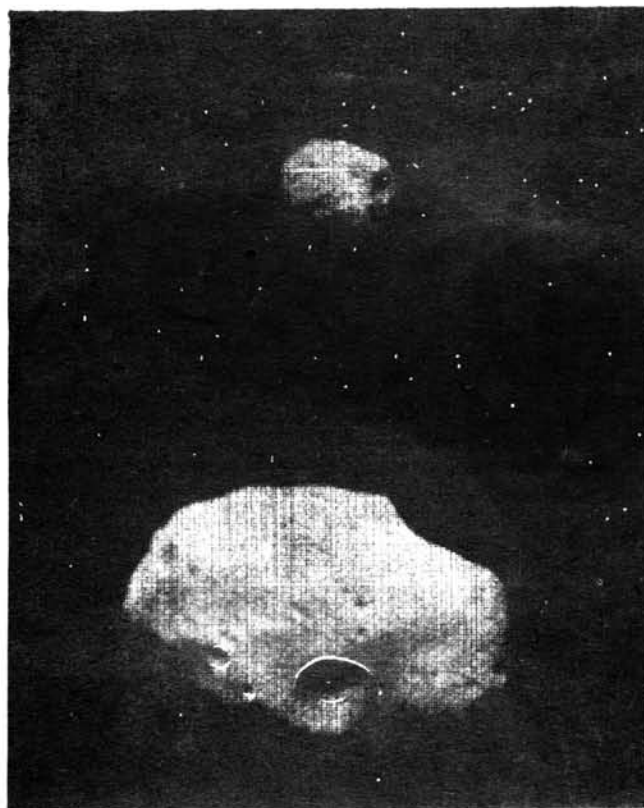
Dr. Rudolph A. Hanel of the Goddard Spaceflight Center said water vapour was detected by Mariner's infra-red spectrometer. 'This is the first spacecraft observation of water in the Martian atmosphere over the South Pole', he said, and 'there is water in other places, but we can't see it at present because of the (dust) storm'.

Water vapour is fairly abundant in the atmosphere, perhaps due to summer melting of the frosty cap. The cap



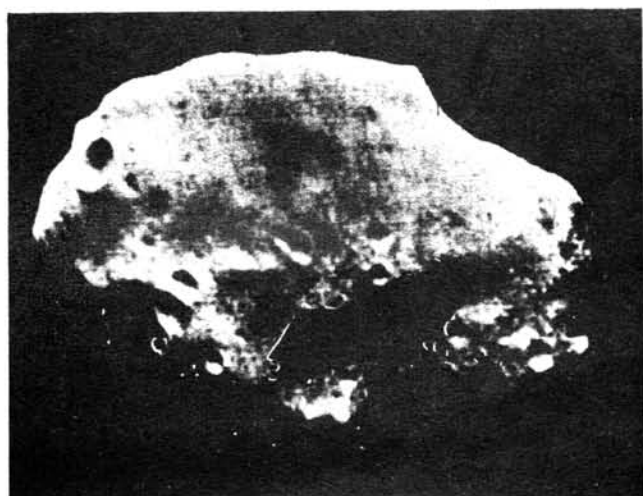
Mosaic of pictures taken by Mariner 9 just before entering into orbit around Mars on 13 Nov. Enhanced by computers at the Jet Propulsion Laboratory in California, they show the south polar cap at lower left and a row of three prominent surface features at centre. The uppermost is identified as *Arsia Silva*, slightly below the equator. It is about 200 km across and has streaks pointing northward more than a 1000 km, thought to be evidence of the Martian dust storm or sand dunes.

United States
Information Service



Top, man's first close-up views of Phobos, the inner moon of Mars, obtained by Mariner 9 on 29 and 30 November respectively. The top picture was made from a distance of 14 683 km during the spacecraft's 31st revolution; the other from 5 540 km during the 34th. *Below*, this computer-enhanced picture is an enlargement of the lower picture above. The shadows give a slightly distorted impression of the moonlet. JPL programme scientists say the profusion of small craters suggests that Phobos 'is very old and possesses considerable structural strength'.

United States Information Service



itself, he noted, has previously been identified as carbon dioxide (dry ice), so the source of atmosphere water remained a mystery.

Reports on Martian temperatures were made by Dr. Arvydas Kliore of the Jet Propulsion Laboratory, Dr. Gerry Neugebauer of the California Institute of Technology, and Dr. Hanel, based on data from Mariner's infra-red spectrometer and infra-red radiometer. The instruments record heat given off by Mars' surface and its atmosphere. Both scientists said the readings may be influenced by the storm, from heat re-radiating off the particles that make up the cloud.

Mariner 9 became the first artificial satellite of Mars following a 15-min. braking burn completed at 00.33 hrs. GMT on 14 November.

Attempts to Soft-land.

Thirteen days later the first of 2 Soviet Mars probes went into orbit round the Red Planet having first separated a capsule 'which delivered to the surface of Mars a pennant with the USSR coat of arms'.

Three course corrections were made to Mars 2 before its arrival in orbit on 27 November 1971. Two power manoeuvres were carried out in conjunction with Earth command from the Yevpatoria, Crimea, deep space tracking station on 17 June and 20 November. The third, made without Earth reference, followed release of a capsule during the final approach to Mars on the same day.

Following the appropriate orientation manoeuvre by the 'autonomous navigation system', the on-board computer calculated the thrust vector and burning time and signalled the appropriate actions. The probe was on a path which would have missed the planet by 1380 km. At 11.19 p.m. (Moscow time) the braking engine fired to insert Mars 2 into orbit. Preliminary tracking data gave the orbital parameters as: distance from surface 1380 to 25000 km, inclination to equator 48°54', period 18 hrs.

It was stated that 'a fundamentally new system of optical, electro-optical and electro-mechanical equipment kept the stations correctly orientated in relation to the Earth'.

A report from the Soviet Co-ordinating and Computing Centre merely stressed the complex engineering tasks involved in putting a vehicle into orbit round Mars and pointed to the 'autonomous astro-navigation system' as the prototype for future flights. On the evening of 27 November, 'information could be obtained at any given moment about the most important stage of the flight of Mars 2 – placing the station in an eccentric orbit – merely by pressing the keys of the switchboard of the video-control device of the multi-channel information system'.

The necessary manoeuvre to put the spacecraft on the required trajectory took place without reference to Earth control. The station's orientation on the Sun and a star and the seeking for Mars was automatic.

Duplicate Mars probe on Earth

At the time of orbital insertion a duplicate spacecraft in the space centre where the Mars satellites were built responded to the same commands fed by cable or radio links. The duplicate responded in precisely the same way as the actual

space probe, writes Boris Kononov in *Izvestia*.

This method of accompanying a space mission had already been tried during the flight of *Venus 4*. The duplicate vehicle was placed in a huge thermal pressure chamber, within which conditions of vacuum were maintained. The machine was cooled by liquid nitrogen, simulating conditions of interplanetary space. There were imitation stars and Sun. If the behaviour of the station seemed strange there was an opportunity of replaying the situation several times on the duplicate so that the best solution could be found. Chess players do something like this when they postpone a game in order to analyse it at home. The same method was used with the *Mars* satellites.

The station's placement in Mars orbit was one of the most important periods of the whole experiment. Twenty-two variants of the station's possible behaviour, depending on its seeing Mars from the right, left below or from on top, were played on the duplicate. In practice, one variant was used, and Earth control could do nothing to help the automaton once its engine was switched on. The signal that the engine had fired took longer to come through than its actual operation.

Mars 3, seemingly an identical craft, went through a similar series of manoeuvres on 2 December. This time, however, the capsule released before the parent achieved orbit 'parachuted down and soft-landed' in the Southern Hemisphere at a position 45°S, 158°W, between the regions of *Electris* and *Phaetonis*.

Despite the low atmospheric density,* the entry followed principles similar to the return from circumlunar flight of Zond probes into the Earth's atmosphere. After a period of aerodynamic braking, the capsule first deployed a small stabilizing parachute and then a large-area main parachute. The design took account of dust storms which could exceed speeds of 100 metres/sec. and sensitive equipment on the capsule was specially protected.

Despite these precautions, however, surface transmissions were short-lived. *Tass* reported that signals from the capsule were picked up by the parent spacecraft and stored for later transmission to Earth on 2 and 5 December, but that 'video signals received from the surface of Mars were brief and suddenly discontinued'.

What happened

is a mystery though surface conditions were far from ideal with dust storms still not fully abated. It may have been an equipment or power failure, or the probe may have been damaged on landing.

The parent vehicle — which before the final braking manoeuvre was passing Mars at a distance of about 1500 km — achieved an orbit with a period of about 11 days.

Mission Objectives

Exploration of Mars could answer vital questions about the origin of life, said Professor Vasily Moroz in an interview published in the newspaper *Izvestia*. If living matter is found, this would provide an opportunity for comparison and analysis and scientists would be able to substantiate theories about the spread of life throughout the Universe and the

chances of finding it. This is perhaps one of the most exciting prospects facing mankind.

The scientist speculated that conditions on Mars could vary from one period to another. For example, it was believed that the polar caps of Mars consisted mainly of carbon dioxide (dry ice) with an admixture of water ice. If it was assumed that in the past temperatures were somewhat milder, then the caps would have diminished or disappeared completely and the volume of carbon dioxide and water vapours in the atmosphere would have been much greater. It may turn out, he said, that the atmospheric density on Mars and the content of water vapour in it increased periodically. This meant that there could be periods more favourable for the development of life.

On 1 December *Izvestia* published interviews with well-known Soviet scientists. Lev Mukhin, chief of the laboratory of exobiology of the Institute of Space Research, said that no biological experiments were being made at the present stage of exploration of Mars. 'This task is too complex to be tackled immediately; this is a task for the future', he said. 'So far we don't know precisely how life formed on the Earth. The study of the evolution of organic compounds on another planet, under different conditions, can give a clue to the solution of this problem. The discovery of organic molecules would serve simultaneously as proof that life can exist on Mars'.

He stressed that we should not lose sight of the ability of living systems to adjust to conditions. One or other kind of protozoa exist everywhere on Earth — in the ice fields of Antarctica and in the Sun-scorched Sahara, deep in the ocean and at the top of Mount Everest.

There is little oxygen on Mars. But even in Earth conditions there exist so-called anaerobic micro-organisms that can exist without oxygen. There are microbes which perish in the presence of this life-giving gas. Some micro-organisms can live even in atomic reactors.

Earth-related Studies

Kiril Florensky stresses that no matter how far into space spacecraft are sent, the main aim of the experiments will always be connected with our planet. Specifically, the exploration of Mars can throw light on the origin of granite of which the continents are formed. The greatest part of our mineral resources is connected with granites. There are serious contradictions in the theory that the granite crust, just as the basalt crust, formed during the 'zone smelting'.

Academician Vernadsky believes that granites are greatly changed rocks of which the former biospheres consisted; that is, they are clay sediments that sank to the depth of the Earth and then rose to the surface. 'It is still unclear if this is so.

Florensky believes that exploration of Mars, a body that is smaller than the Earth but larger than the Moon, is very important in this respect. 'We shall be able to establish whether the process of the formation of granite has a universal nature or whether this process is typical only for the Earth', he said. 'It is possible that the latter view is correct'.

[to be continued.

* Surface pressure is 5 - 7 millibars, similar to conditions over 30 km above the Earth.

ASTRONOMICAL NOTEBOOK

By Prof. J. S. Griffith

The Ice Caps of Mercury!

It is shown that the suggestion of ice caps on Mercury is at least plausible.

In a letter to the 'Observatory' (1), V. A. Firsoff puts forward support for the existence of ice caps on Mercury. The average temperature of Mercury is around 450 K, but in the absence of an atmosphere the temperature far from the subsolar point will decrease by a factor varying as the $(\frac{1}{2} \cos \phi)^{1/4}$ where ϕ is the angular distance between the subsolar point and the equator of illumination. As Mercury takes over 170 days to rotate about its axis, we would expect the conditions on the night side to be rather cold and once snow (or hoar frost) has fallen, the consequent increase in albedo would lead to a lower temperature – even at mid-day. Firsoff's calculations indicate that even in the presence of a thin atmosphere a snow cap would be stable above 80° from the equator of illumination (the locus of the subsolar point). I look forward to more discussion (and perhaps observation!)

REFERENCE

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A Contribution towards the Theory of the Formation of the Planets

A theoretical analysis of the settling of gas grains is presented that supports McCrea's theory of the formation of the solar system.

In order to use the available raw material (of similar composition to the Sun or normal interstellar material) to form our planetary system, we need to remove most of the hydrogen and helium before the formation of the Earth and the other terrestrial planets. Either the segregation of the material took place before the agglomeration into proto-planets, or the agglomeration is followed by segregation (in a body of the size of a major planet).

In the second case we need a process to separate out the hydrogen and helium (e.g. [1]) and then another process to remove the hydrogen and helium. The work of McCrea [2] proposes that the Sun is formed by the agglomeration of cloudettes (floccules) with around 1000 floccules captured in orbit around the central proto-Sun. Collisions lead to the formation of planetary sized 'globes'. In ref. [3] the formation of these globes (with radius ~ 0.2 A.U., mean density $2/3 \times 10^{-8}$ g cm⁻³ and temperature ~ 100 K) is considered in detail. The condensation takes around 1000 years, and the mass loss (by the release of gravitational energy in the form of heat leading to an evaporation of the lighter molecules) is sufficient to explain (together with the tidal dispersion effects and auxiliary heating of the Sun) the form of the terrestrial planets, yet not efficient enough to render Jupiter and the outer planets free of hydrogen and helium.

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Cepheid Variables

A new relationship for Cepheid variables is obtained, and Cepheids are found to be a reliable foundation for the determination of galactic distances.

The use of Cepheid variable as distance indicators (celestial lighthouses) depends upon showing that Cepheids from different galaxies obey the same period-luminosity-colour relationship. For several years it has been known that differences exist between Cepheids in the Galaxy and those in the SMC (Small Magellanic Cloud). In 1940 it was pointed out [1] that the SMC contains many more Cepheids with periods between 1.5 and 4 days than our Galaxy; twenty years later it was found that SMC Cepheids with periods less than 10 days were consistently bluer than those with similar periods in our Galaxy [2], and no large amplitude Cepheids (1.6 mag) were found in our Galaxy, whereas in the SMC the short period Cepheids did have such amplitudes [3].

In ref. 4 it is shown that all 3 points are probably related, and explainable in terms of a single phenomena – that the position and width of the Cepheid instability strip in the (M_{bol} , $\log T_e$) – diagram is the same for all galaxies, but the way this region is populated depends on the particular galactic evolution. It is shown that the period-luminosity-colour relationship is equivalent to a period-luminosity-amplitude relationship, that interstellar or intergalactic reddening can be deduced from the colour implied by the amplitude of a Cepheid, and that (as a period-luminosity-amplitude relationship is colour independent), distance moduli to galaxies can be obtained by observations in one colour.

The lack of evidence for a difference in the characteristics of Cepheids from galaxy to galaxy justifies their use as the foundations of a distance – scale calibration of other indicators in local galaxies, which in turn will be used at larger distances for determination of the Hubble constant for the red shifts/distance relationship for galaxies.

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Low Mass Objects that have Gravitationally Collapsed

Has the Sun a black hole at its centre? Do very low mass objects exist in gravitationally collapsed form? It is suggested that the answer to both these queries is affirmative.

Stars with a mass greater than about 1.5 times the solar mass will, when their nuclear fuel supply is exhausted, collapse under gravity to produce a 'black hole' with radius the Schwarzschild radius of $2GM/c^2$. The only part of the star that would be detectable in the universe from which it collapsed would be its gravitational field, and it has been suggested that Weber's observations (refs. 1,2,3) of gravitational waves indicate a stellar collapse rate in the galactic nucleus of over one a day. In ref. 4, S. Hawking suggests the presence of a very large number of collapsed objects of much smaller mass. Basing his work on the 'Chaotic Cosmo-

logy' of Misner (ref. 5) in which initially large random fluctuations of all length scales are later damped out, Hawking shows that there would have been many volumes in which gravitational energy greatly exceeded the kinetic energy of expansion. In these regions, a collapse would have occurred, but in order for total disconnection from our universe, the mass has an upper bound. It is expected that the lower bound is around 10^{-5} g. with the number of objects being very large. Sandage (ref. 6) has obtained measurements that indicate an average density of the universe as around 10^{-28} g. cm^{-3} . Is the major portion of the universe collapsed objects, whose presence is indicated by their combined gravitational fields?

Hawking deduces other properties of 3 small objects. It is possible that some unidentified tracks on bubble chamber photographs are caused by collapsed objects. The Sun could have acquired a mass of 10^{17} g. collapsed objects which may be coalesced in the centre to form a single black hole of radius 10^{-11} cm. Perhaps an explanation of the difference between the predicted and observed neutrino flux of the Sun?

Later evolution of the Sun into a neutron star would lead to a steady accretion of matter by the hole at the rate of 10^{10} g. per year, leading to a shrinkage of the solar surface (pulsar-quakes?).

In 10 million years the Sun would be totally absorbed, the later stages being extremely rapid (giving 'Weber-like' gravitational waves?).

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Water in Stars

Long period Mira-type variables are found to have their water emission strength at 1.35 cm anticorrelated with the water absorption at 1.9 μ .

It is, perhaps, unfair to write of water at 2,500 deg., but the existence of H_2O molecules is certainly observed. Both hydrogen and oxygen have long been known to exist in stellar interiors, and it is possible that in the atmospheres of pulsating cool stars they could combine. Below 2,500 deg. water becomes fully associated, and if the water molecules formed at low levels in the atmosphere are forced outwards (having energy transferred to them from the large amplitude pulsations) one could have a consequent mass loss, with the expelled water molecules accumulating in circumstellar regions. This type of situation is discussed in reference [1], where the author uses such a model to explain the anticorrelation of the water emission strength at 1.35 cm with water absorption at 1.9 μ .

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Stellar Collisions

The possibility of 2 colliding stars coalescing to form a more massive star and the simulation of the collision rate in a system of the order of 100 million stars are discussed.

Suggestions have often been made that compact sources of high luminosity (nuclei of Seyfert galaxies and QSO's) might be very dense stellar systems in which collisions between stars take place with very high frequency. There are 2 proposed energy sources. The first involves the disruption of colliding stars and the release of large amounts of gas, while the second involves the coalescence of colliding stars, leading to a number of very massive stars and hence a greatly increased supernova rate.

In order to determine the supernova rate it is necessary to solve the problem of the evolution of a system of stars in which coalescing and disrupting collisions, star formation and stellar evolution are all taking place. In ref. [1] this problem is approximated by using a direct Monte Carlo simulation of stellar collisions. There are 2 types of 'soft' collisions. The first is a grazing collision, in which the stellar cores do not actually come into contact, while the second 'close' collision involves contact of the 2 cores. Either the stars may interchange some atmospheric material and proceed on their way with slightly decreased relative velocity, or the energy losses are great enough for the stars to remain in very elliptical, bound orbits, undergoing repeated collisions until a single object or close binary remains. Taking models of between 10 million to 100 million stars, the evolution of the systems are considered. It is found that the supernova rate from coalesced stars is insignificant compared with the total luminosity of the system.

However the supernova rate resulting from new stars formed in the centre of the system from the gas liberated in disruptive stellar collisions could well give the energy out flow observed in QSO's.

Very massive stars may well build up and the eventual gravitational collapse of these objects could be a significant source of energy. The direct enhancement of the supernova rate by stellar coalescence is not important, but the enhancement of the luminosity of a dense stellar system by coalescence may well be very important.

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Rapidly Varying Blue Stars

A new instrumental system has been developed which enables the detection of variations in luminosity at a time scale of the order of 1 ms.

The process by which stars evolve into white dwarfs is still unclear. Certain rapidly varying faint blue stars may constitute an evolutionary stage prior to the true white dwarf stage, as they have colour and spectra very similar to white dwarfs. In ref. 1 a new instrumental system developed specifically for the study of rapid luminosity variations, with a time scale varying by a factor of 10^4 from 1 ms per reading to one every 10 s. is described.

Using a timing system based on a rubidium clock synchronised with the U.S. Naval Observatory's caesium clock in conjunction with a general purpose digital computer linked to an IBM 1800 computer, R. E. Nather and

B. Warner have found that their observations are now basically only limited by the rate of detection of photons. Some observations obtained by the authors are discussed in ref. 2 where a new model for the binary dwarf nova U Geminorum is described.

U Gem is a very active system with both components near the mass of the Sun. The cooler component is probably an early M dwarf, filling its Roche lobe and spilling material into a gaseous ring around the hot star. There is a 'hot spot' on the ring, possibly made luminous by the infalling material from the cool star. The hot star does not appear to undergo eclipse, as seen from the Earth. The hot star is either a white dwarf or of some undetermined magnitude, as it may be masked by the optically thick luminosity (in the form of cylindrical envelope). The bright spot is assumed to be the only source of rapid light fluctuations in U Gem, with subdued flickering caused by the radiation from the hot spot passing through the optically thick nebula. The hot star may be subject to outbursts, and the authors suggest that the nova will appear very bright in the far ultraviolet and propose use of the OAO2 satellites for observations. The period of U Gem has increased during the last 5 years.

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Galactic Wakes

Solar and stellar winds have become familiar - now the topic of galactic winds and wakes is discussed.

Various methods have been used to determine the density of the intergalactic medium. Little success has been achieved. For cosmologists, this density has interests, and it may be more easy to detect fluctuations in the intergalactic medium than to determine its low mean density. As galaxies pass through the gas their gravitational fields may so affect the medium that their wakes may be detectable (A gravitational probe). The physical conditions in the medium may well be partly determined by the interaction of the galaxies with the gas.

Early work on a similar problem was connected with the accretion situation in the solar system [1] and [2]. A column of high density gas is formed on the downstream axis of symmetry. In this high density area, collisions may take place. The situation becomes complex when forces other than gravitational are taken into account. Thermal motions in an ionized medium lead to the formidable problem of accretion in a gravitational plasma. In ref. [3] a model is presented in which the flow upstream is represented as a gravitational problem, while the flow downstream is treated hydrodynamically. The 2 regions are joined by a collisionless shock wave. Thus the assumption is that the shock wave increases the temperature of the gas so that it is no longer justifiable to consider the problem solely as one of gravitation. The drag on the moving galaxy is also evaluated, and the rate of energy loss of a supersonic galaxy

determined.

After determining the physical conditions in both regions, the generation of X-rays from the wake is considered, and it is found that certain clusters of galaxies may give detectable radiation.

The author concludes that in 10^{10} years, all ambient gas within 10^6 light years of most galaxies will have passed through galactic accretion shocks, with the characteristic galactic-gas velocity of 4×10^6 cm sec⁻¹ leading to a heating of the gas to around one million degrees. It appears that individual galaxies and the gas around them do not independently take part in the cosmological expansion, whereas clusters of galaxies do take part. The observed X-ray background radiation could be due to the bow and wake-shock heating of the gas around our Galaxy if the local density of gas exceeds 3×10^{-4} particles per cubic centimetre.

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The Timing of Light Flashes from the Crab Nebula Pulsar

Residuals from the smooth ephemeris of the pulsar do not show any evidence of the 'oscillation' that preceded the 1969 star quake. The pulsar may have developed oscillations that led to the star quake, and that it is now in a stable, non-oscillating configuration. The 'braking index' does not fit in well with any of the simple models for loss of energy.

Study of the Crab nebula pulsar NP 0532 has contributed more to our present understanding of pulsars than the study of any other single object. It also offers an opportunity for comparison to unprecedented accuracy between both man made and natural clocks in the solar system and an external clock. The rate of changes of the pulsars due to the acceleration of the solar system is less than 3×10^{-15} . This is certainly less than the value of 4×10^{-13} observed for the Crab pulsar, but the addition of measurements of other pulsars will give a new observational limit to the acceleration of the solar system.

The 'braking index' n is defined by the secular behaviour of the pulsar, and is model dependent. The value of n is 1 for relativistic model of stellar wind deceleration, upward of 3 for magnetic-dipole radiation and 5 for gravitational radiation. In ref. [1], n is found to be 2.23, which could be accommodated by a mixture of braking mechanisms. The authors do not confirm that oscillatory nature of the residuals previously reported. These oscillations were detected before the irregularity or 'glitch' in the pulsar reported in ref. [2], which has been widely regarded as a star quake.

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SOCIETY NEWS

22nd (1971) I.A.F. Congress

The annual Congress of the IAF is probably the most successful in the International Aerospace calendar. It is certainly the oldest and very well attended. Some 800 participants registered for the 1971 Congress at the Palais des Congress at Brussels, to attend the 21 technical sessions and to hear 148 papers read.

The opening ceremony was attended by H.R.H. King Baudouin, the American astronauts Scott, Irwin and Worden, and the Russian cosmonaut, Yegorov. The ceremony was this year kept shorter than usual, or so it appeared — perhaps the speeches were more interesting than usual.

Special sessions showed slides and movies of Apollo 15 and of the Lunokhod Film shot from the Moon Rover as it was driven across the Moon gave an impression of the grand scale of the scenery at Hadley Rille, the forward motion of the camera giving a good substitute for stereoscopic vision. Remarkably sharp still pictures showed more than 70 strata in one 15,000 ft. mountain peak, and it is clear that many years of interesting work lie ahead in selenology (geology of the Moon).

Technical Sessions

The topics of the technical sessions were applications satellites; safety in youth rocket experiments; astrodynamics; fluid mechanics; design aspects of scientific spacecraft; telemetering and data management; propulsion; education; materials and structure; space transportation problems and lastly, bioastronautics. In addition, the International Academy of Astronautics ran sessions on space rescue, history of astronautics, cost reduction in space operations and an international orbital laboratory.

The session on cost reduction included a British paper on 'overmanagement' by Mr. A. V. Cleaver. Broadly, he applied the Marks and Spencer principle of balancing loss by theft against salaries paid to store detectives to the technique of project management. Overmanagement results in knowing more and more precisely how many nuts, bolts and washers were used, and how many were wasted, and in what manner, but it never results in their replacement by perhaps a technique for welded construction.

Sessions on space shuttle and space tug and also Earth resources and environment were very popular, though some of these overlapped.

The Congress was also notable in being the first to have a students meeting. Britain was particularly well represented both in authors of papers, and attendees.

Social Occasions

Aside from numerous private parties, there were cocktails on Monday and Tuesday evenings, the latter taking place in the 17th Century Town Hall of Brussels, which has an interior as interesting as its floodlit exterior would suggest. Friday evening was the occasion of the Banquet, at which the \$1,000 Daniel and Florence Guggenheim award was presented to Prof. L. Broglio, Dean of the Aerospace Engineering Department of the University of Rome.

Interesting as these functions were, the entertainment of the Congress reached an all-time high on the Wednesday afternoon, when 800 delegates and wives visited Bruges by special train. On arrival we were met by special guides, who divided us up by language groups, and walked us round their city.

There were interesting reactions from delegates to the

detailed paintings and statues recording how a particular judge, in the habit of accepting bribes, was caught out by his King, and ordered to be skinned alive. Even the executioner's assistant could not bear to look.

At 7 pm, all the parties met in the main square of the Town, where 4 buglers in medieval dress on the balcony of the carillon belfry, summoned all to supper — and what a supper it was! Served by buxom wenches in the medieval style and complete in every detail — including the absence of potatoes. A band of medieval musicians circulated among the diners, playing tunes appropriate to the 36 guest countries. It seemed that our Belgian hosts still remembered with affection the British Tommies, for the first tune was 'Pack up your troubles in your old kit bag'.

Liquid refreshment was served in large beer mugs decorated with IAF insignia, long to be treasured in memory of a very happy occasion.

The Host Society, A.B.I.T.A. (Association Belge des Ingenieurs et techniciens de l'aeronautique), and their President, Prof. Nicolet, together with IAF President Jaumotte, are to be congratulated on almost successful Congress. Their excellent planning was apparent to all.

Future Congresses

The 23rd Congress will be held in Vienna from 8-14 Oct. 1972. The venue will be the Hoffburg.

The 24th Congress will take place in the USSR in 1973. A possible venue is Kiev in the Ukraine.

Invitations for future Congresses have been received from Italy, India (1974), and Israel (1975).

Meetings in Australia

The most recent meeting of the South Australian Group took place on 17 Sept. 1971 when Mr. Aidan Moore spoke on 'The Geology of the Solar System', which included a description of moon rocks brought back by Apollo 11. The film *Blue Streak in Space* was also shown. The successful evening concluded with discussions over supper.

The local Chairman is Mr. Ivan Winter with Dr. B. A. Gooden as local Secretary and Treasurer. Details of future meetings can be obtained by writing to Dr. Gooden at 21 Williams Avenue, Dulwich, South Australia 5065.

Bankers Orders

The last postal strike showed the great advantage to the Society where payment is made by standing order through a UK Bank Account. In this way payments could be transmitted direct without the intermediary of the post. All members with UK Bank Accounts are urged to consider most carefully this way of remitting for the future. Bankers Order forms are available from the Secretary on request. Payments should be made direct to the Society's Account at National Westminster Bank, 290 Walworth Road, London S.E.17. Code 60-22-27, Ref. S/S A/c. 34649972.

Not only does payment in this way take care of omissions, but it always can save the Society an enormous sum in time, effort and postage charges in issuing numerous reminders.

With the cost of labour so much at a premium, and particularly as we have such a small staff, the cost of reminders becomes very high and the saving to the Society could be very substantial indeed.

It is hoped that these reasons will commend themselves to all members able to respond.

4th Symposium on 'Materials in Space Technology'

The 4th Symposium on 'Materials in Space Technology', held at University College, London, on 29-30 September 1971, once again followed the general pattern of previous meetings with sessions on high strength materials, refractory materials, electronic materials, manufacturing processes and applications of materials in space technology.

The first lecture by Prof. Hancock (Cranfield Institute of Technology) reviewed the whole field of metals and mentioned comparatively new high strength and weldable aluminium alloys 2021, specially produced for cryogenic applications. Titanium was finding increasing applications and the whole technology of titanium fabrication was on the verge of a breakthrough because of the 'superplasticity' phenomenon. Another interesting group of titanium alloys were the NITINOLS which have a 'memory' and can be caused to revert to an earlier shape by heating. Future developments in high strength steels giving strengths up to 3095 MN/m² (200 tons/in² for those not yet converted) was foreseen.

Those wondering whether we could save half the weight of existing steel structures were brought back to Earth by Mr. Langstone (Bristol Aerojet Ltd), when he presented his paper on 'Fracture toughness of high strength steels'. By using fracture toughness concepts as a means of inspection and quality control, considerable cost savings were envisaged.

Beryllium reared its toxic, difficult to manufacture, etc. head again in the paper by Mr. Cranidge MOD (PE), ROF Cardiff, but despite these disadvantages it continues to find applications in aerospace.

Composite materials received rather poor support compared to the previous meeting with only 2 papers. Prof. Morley (Wolfson Institute of Interfacial Technology) described a very interesting technique of achieving toughness in fibrous composite materials and Mr. Parmee (Rocket Propulsion Establishment) described a comparatively new class of materials, namely, carbon fibre/carbon composites, possessing high strength and high temperature stability. Carbon fibre reinforced plastics should have been represented more but somehow were left out.

Ceramic materials were covered by a review of the common ceramics, by Mr. Lloyd (British Ceramic Research Association), who described their properties and by Mr. Davies (Fulmer Research Institute) who gave an excellent presentation on how we should design with these materials. However, our sympathies lie with him because he has to try and convince people that the thicker you 'make it' the weaker it gets.

Electronic materials were adequately dealt with by Messrs. Oliver (Robert Gordon Institute), Newman (Allen Clark Research Centre, Plessey Company) and Webb *et al* (Ferranti). In the discussion we detected a spattering of commercial one 'upmanship' creeping in with questions such as 'how could you make it that thin without holes' etc. However, electronic materials and systems still seem to be getting smaller and their reliability improving.

Two sessions devoted to manufacturing processes, a new departure for this series of symposia, were well supported. Dr. Johnston (Murex Ltd) gave a comprehensive review of the fabrication of the common refractory metals, tungsten, molybdenum, tantalum and niobium. The major hurdle to further aerospace applications of these metals still appears to be their lack of oxidation resistance. A possible solution to this problem was offered in the paper by Mr. Gardner

(Union Carbide) on an advanced metal-ceramic coatings possessing a wide range of oxidation and wear resistant properties. These coatings are applied by plasma-spraying or by a detonation gun, a novel but extremely noisy development in which hard surface coatings are applied by the controlled detonation of oxygen and acetylene which propels the powdered coating material at the surface.

Mr. Duncan (Torvac Ltd) reviewed the application of electron beam welding and vacuum brazing to the joining of aerospace materials. He also described his Company's process for producing metallized plastic sheet, of the type used on the Apollo Lunar Module, for thermal control. Dr. Pugh (National Engineering Laboratory) then brought the meeting down to Earth again with a paper on the effect of hydrostatic pressure on the properties and forming characteristics of materials. Techniques such as hydrostatic extrusion have great potential for the mechanical working of brittle materials, but inexplicably to us, do not appear to have been exploited industrially.

The expanding technology of chemical vapour deposition was reviewed by Mr. Hayman (Fulmer Research Institute Ltd). This technique has been applied successfully to the tungsten coating of rocket nozzles, and to the production of free-standing rhenium tubes and nozzles for resistojets. Concluding the session, Mr. Anderton (Bristol Aerojet Ltd) gave a paper on the use of numerical control in the welding of rocket motor cases.

Application of materials in space technology were covered by papers on pyrolytic graphite coated rocket nozzles (Mr. Parmee, Rocket Propulsion Establishment), hydrogen resistojets (Mr. Sherwood, Rocket Propulsion Establishment), and manufacturing processes under zero gravity (Dr. Bauer, ERNO).

Overall the conference appeared to be well received but attendance was down on previous meetings, perhaps reflecting a decreasing activity in the field of aerospace technologies in the UK. Attendance was only 60% of that in 1969 and only 43% of that in 1961.

8th Space Study Meeting

Nearly 50 members attended the 8th Space Study Meeting held in London on 17 Nov. 1971.

First to speak was Dennis Carton, on *Possible and Impossible Space Propulsion Systems*. Starting with an illustration of two main types, i.e. those which obtained their propellant from their environment and those which did not, he then sub-divided the systems still further, moving gradually into the more exotic e.g. electrical systems, with enormous potential speeds — provided that practical problems in the way of realisation (e.g. weight penalties) could be overcome.

From the practicable he moved logically into ideas which, while seeming practical, offended some law of nature. These gradually moved towards gravitational propulsion (but with the reservation of the special case of the gravitational 'swing-byes') to those which were almost pure prayer.

Geoffrey Perry followed with an updated version of his earlier talk on *Recoverable Cosmos Satellites* summarising the position up to Cosmos 450, and illustrating his talk with many recordings and slide interpretations of various Cosmos satellite signals. This was quite fascinating and sparked off a lively discussion which revealed with astonishing clarity how wide was the variety of data which could be obtained with relatively simple equipment plus a good deal of thought.

BOOK REVIEWS

Edited by L. J. Carter

Man on the Moon

Ed. By E. Rabinowitch and R. S. Lewis, Basic Books Inc.,
Dolls. 6.95, 204 pp. 1970.

The impact of man's emergence from the 'womb' of the Earth, to visit interplanetary space and the surfaces of satellites and planets, on science, technology and international cooperation is the topic of this volume. Sixteen experts in the physical and social sciences were invited to contribute.

The Moon landing is seen as a climatic event in the evolution of man, with Sir Bernard Lovell suggesting that it will have a cataclysmic effect on society. He advocates international cooperation to send a manned flight to Mars in the 1980's.

Linking expenditure on Apollo missions with priorities such as pollution, housing, urbanization problems is the concern of several authors. The application of the successful scientific-industrial-social integration required for Apollo to other 'super-problems' (pollution, food production, waste disposal, transportation) may be the most important achievement of the space programme, according to E. Stuhlinger.

It is predicted by M. L. Harvey that the Russians will orbit the first manned space station (!), but to S. Hyman the long range political consequences of landing on the Moon are as predictable as the history of the United States would have been in the 1492 era when Columbus landed on Salvador. Other articles include those on the astronomical discoveries resulting from orbiting observatories and the impact of lunar exploration on astrophysics and cosmology. Wernher von Braun predicts that manned excursions in the solar system will soon be forthcoming, while more technological applications are of the Apollo automated checkout and monitoring systems to the whole spectrum of industrial production.

A fascinating text, somewhat outdated now, but one that is well worth reading and thinking about. The dust cover has the double 'o' in Moon replaced by 2 photographs of the Moon!

Prof. J.S. GRIFFITH.

Space Shuttles and Interplanetary Missions

Ed. L. Larmore & R. L. Gervais, American Astronomical Society Publication, 1970, pp. 488, Dolls. 17.75.

This is the second of 2 volumes devoted to the proceedings of the 16th Annual Meeting of the American Astronomical Society held in Jun. 1970. The name of the meeting was *Space Station and Manned Planetary Exploration*. With the present space programme reaching its final stages it was felt that this topic was most suitable in view of the next phase of development.

The book is divided into 3 sections under the headings Space Shuttle, Precursor Missions and Planetary and Lunar Space Stations.

A brief account is given in the 1st section of the Phase A Integral Launch and Re-entry Vehicle (ILRV) Studies by NASA which were completed late in 1969. The overall aims were to reduce development costs and to improve systems reliability and crew safety. A fully reusable 2-stage system was considered to be the most economical concept and 5 studies based on this conclusion are described briefly. Other papers in this section are concerned with atmospheric manoeuvres, trajectory optimization, propulsion systems and operational aspects of space shuttle systems. In this

section there is also an article of a descriptive nature on *Space Shuttle - space station integration issues*. The motivation here is the Phase B definition studies of the United States Space Station, NASA contracts for which started in Sept. 1969. These studies called for a preliminary design of a 12-man space station capable of operating in a low Earth orbit for a minimum of 10 years. The date of launch is anticipated as late 1977. This article discusses problems of rendezvous, docking, cargo and crew transfer and what amounts to the day-to-day maintenance and running of a space station.

The second section of the book, on precursor missions, has quite a different outlook. Here manned as opposed to unmanned missions are contrasted and discussed and various missions analysed. An interesting observation in this section is that unmanned Mercury orbiter missions are grossly equivalent, in both complexity and energy requirements, to manned lunar orbiter missions such as Apollo 8. Unmanned exploration of Mars is considered and also exploration of the outer planets. This latter project has some degree of urgency attached to it. The alignment of the outer planets is particularly suitable for this kind of mission in the period starting about 1976. Such an alignment will not occur again until 179 years have elapsed.

The final section on Planetary and Lunar Space Stations contains some articles referring to the use of nuclear engines. The attraction of nuclear propulsion is that the payload would be greatly increased. However, there are problems involved and these are discussed.

In all, this volume contains 17 articles and is liberally provided with diagrams and graphs. As with so many compilations of this kind, there is something of interest for everybody.

Dr. W.J. ROBINSON.

Aerospace Research and Development

Ed. Dr. E. A. Steinhoff, pp. 488. Vol. 24 of American Astronomical Society Science and Technology Series.

This volume represents a tribute to Dr. Adolf George Baemker on the occasion of his 75th birthday in Jul. 1966. Dr. Steinhoff, the Chief Scientist at Holloman Air Force Base, where the meeting was held, was organiser and proceedings editor. He was assisted by over 20 contributors comprising scientists and engineers who have achieved world wide recognition in their fields and who are supporting the Aeronautics and Space Age on a very wide front. The scope of the matter contained within the covers is impressive. The papers are also a wide mixture of form, format and status. Some are important contributions in their own subjects with equations, many figures and references; others are entirely the written word. Unfortunately there is no subject index, no discussion, and one third of the papers are in German.

A number of the contributions are important archival papers. Dr. Adolf Busemann and friend contribute a paper upon transient pressure fields behind plane supersonic blast waves. Professor H. Herman describes an analytical investigation of inviscid flow with non-equilibrium oxygen around cylinders and cones. O. M. Stuetzer uses space charges to modify turbulent boundary layers. A most comprehensive paper by J. N. Plendl outlines new concepts in the physics of solids. The study treats infra-red spectra,

specific heat, bulk modulus, change of compressibility with pressure etc. Professor Otto Lutz summarises much recent work on thermochemical-gasdynamics of various high temperature processes. Professor H. Barth simulates engine flight performance. Professor E. R. G. Eckert proposes a new method for gas to gas film cooling based on heat and mass transfer.

If you are attracted by the title, I suggest you first borrow a copy; it may not contain what you seek!

D.S. CARTON.

Stellar Rotation

Ed. Arne Slettebak, D. Reidel Publishing Co., 355 pp.

This collection of 6 review papers is complemented by 33 contributed papers to detail the state of knowledge about rotating stars as it existed in Sept. 1969. Advances in the subject have, of course, been made since then, but this work is invaluable to those interested in learning about stellar rotation. Topics range from the effects of rotation on stellar interiors, evolution and atmospheres, through stellar rotation in binaries, clusters and special objects, to the statistics of stellar rotation and the rotation of the Sun. Papers that may be of interest to readers of Spaceflight include one on fission and the origin of binary stars in which it is concluded that, 'although fission remains unproven, there are now no strong theoretical arguments against the process', and the concluding section on the possibility of a differentially rotating oblate Sun.

Prof. J.S. GRIFFITH

Vanguard — A History

By C. M. Green & M. Lomask, David & Charles, 308 pp, £5-25.

Within 30 months from the American announcement that its contribution to the I.G.Y. of 1957-8 was to be an Earth orbiting satellite, Vanguard I was transmitting, from orbit, information on the shape of the Earth and its atmosphere, and by the end of the extended I.G.Y. it had been joined by the 2 further successful satellites in the series.

This carefully documented account of Project Vanguard from its antecedents in the BIS Earth satellite studies to the discoveries yielded by the programme is primarily a study of the project's science and technology. Official historians in this country are hampered by bureaucratic secrecy; not so these authors — The Defense Department bared its soul so that the fullest information possible was made available.

The technical scope of Project Vanguard was enormous, mainly because the Naval Research Laboratory was given a low priority and had to create its own facilities. One story illustrates the lack of sophisticated communications possessed by NRL even at so late a stage as Jan. 1958 when public opinion was demanding a reply to the Sputniks. The army and NRL collaborated to launch Vanguard hardware. Prof. Van Allen's permission was required, but he was on an ice-

breaker in the South Pacific and beyond the range of the navy's most powerful transmitters. Someone suggested sending a Western Union wire and, to their astonished amusement, a reply with Van Allen's consent came within hours.

Political difficulties were at least as great as technical problems but Vanguard is not a political essay and has no axes to grind, so that often-heard questions such as why military missiles were not made available for satellite launching before 1958, are examined dispassionately.

Very useful appendices on I.G.Y. launchings are followed by an exhaustive index. Regrettably, the illustrations are monochrome and there is no detailed pictorial breakdown of the launch vehicle, all in all however, it is fine coverage of the project which should be of interest at all levels. The subject is still controversial and though the present treatment will not meet with full approval everywhere, they have shown that without Vanguard a manned landing on the Moon in 1969 would have been highly unlikely.

T. MACKENZIE

Space Technology and Earth Problems

Ed. C. Quentin Ford, American Astronautical Society, 417 pp. 1970.

The wealth of new skills and techniques evolved to solve problems in the aerospace field are finding increasing applications in more 'down to earth', areas. Workers in fields as diverse as Urban Planning and Underwater Exploration are making use of the 'technological fallout' from the space programme. To provide a forum for an exchange of results and information, on work of this type, the A.A.S. organised a symposium on 'Space Technology and Earth Problems', in Oct. 1969, which led to the present proceedings.

Of the 64 papers originally presented about half have been fully documented in the book. The remainder are represented by single page abstracts, accompanied by the necessary references to the complete paper in the A.A.S. Microfiche Series.

Excluding those papers presented during the introductory session of the symposium, the remainder have been classified into 6 different categories, i.e.:-

- (a) *Atmospheric Systems*: Dealing with topics such as Air Pollution, Weather Prediction, and experiments in Atmospheric Physics.
- (b) *Communication Systems*: Some papers in this category deal with overall system concepts such as Urban Communications while others are concerned with individual problems, e.g. Phase Detection and Bit Synchronization. Most of the papers are, of necessity, of a fairly mathematical nature, and as such will not be of great interest to the general reader.
- (c) *Land Systems*: Here, the problems considered include, The Remote Sensing of the Environment, Food Production, Mapping, and Earth Resources Management.
- (d) *Ocean and Water Systems*: Covering a wide variety of subjects such as, Underwater Exploration, Pollution, Oceanography and Hydrology studies by satellite, and the modelling of the Ocean Environment.
- (e) *Sensors and Data Management*: A variety of topics

are covered including Project Planning, On Board Computers, and the Correlation of Data from Multiple Sensors. Three of the abstracts indicate papers of a highly mathematical nature.

- (f) *Transportation Systems*: The last section in the book, contains papers on such subjects as Air Cushioned Vehicles, Guidance and Control for High Speed Train Systems, and City Planning by computer modelling techniques.

With such a diversity of subject matter, this book should prove to be highly informative to anyone interested in the applications of space technology to Earth problems. Naturally a scientific and technical background will be required of the reader, but, as the papers are written, in the most part, with a view to being presented before a varied audience, specialist knowledge is not required to appreciate their content. The quality of presentation of the papers is, in general of a high standard, and the reproduction of diagrams and photographs is excellent.

This book is to be highly recommended to anyone seeking an insight into the application of aerospace techniques to the solution of problems in other fields.

I. PRYKE.

Stellar Atmospheres

By D. Mihalas, Freeman & Co. 1970, 463 pp. £7.50

This textbook gives a thorough account of the way in which the classical theory of radiative transfer may be used to describe the energy flow within stellar atmospheres. Written by one of the foremost authorities on the subject, it deals mainly with the recent developments in this field, many of which are based upon the fundamental research of the author.

The introductory chapter introduces the basic definitions used in the derivation of the equation of transfer and is followed by chapters on the grey atmosphere, the equation of state, opacity, statistical equilibrium, LTE and non-LTE model atmospheres for the continuum, the line spectrum, the line absorption profile, the redistribution function, classical treatments of line transfer, the 2-level atom, the multi-level atom and the effects of line blanketing on stellar atmospheres.

The basic model considered by the author is that of a stellar atmosphere that is in radiative, hydrostatic and steady-state equilibrium and this has been done in such a way that the various methods described for computing the radiation field and the occupation numbers of the atomic states lend themselves to certain other spectroscopic problems than those associated with stellar atmospheres. For example they may also be used in the study of spectra in the laboratory, plasmas and the various atoms and molecules found in interstellar space.

Inevitably, a book of this kind requires a working knowledge of mathematics and in this respect it will be of little interest to the layman. Its real value is that it provides, in a single volume, all of the basic theory needed for the advanced student taking a course in astrophysics. With this knowledge, the reader will be in a position to follow all of the current literature on the subject.

The book is very well produced and is singularly free from errors. The diagrams, in particular, are very clear. At

the end of the text there are a useful list of references and an extensive glossary of physical symbols.

The price is not too high for a book of this kind, and as a standard work on the subject, it can be recommended without hesitation for University courses in Astronomy.

Dr. J.S. GLASBY.

Understanding the Earth.

Ed. by I. G. Gass, P. J. Smith, R. C. L. Wilson, M.I.T. Press, Dolls. 9.25, 355 pp. 1971.

Prepared for the Earth Sciences component of the Open University's Science Foundation Course, this stimulating book is written by 22 scientists of international reputation.

It starts with chapters on minerals, rocks and the dating of geological time. The Earth as a planet is then described, with its primeval history outlined. Changes since that time in the surface of the Earth and the life on it are sketched. Continental drift and ocean-floor spreading are the subjects of the next 2 chapters, followed by chapters on the Earth's magnetic field, plate tectonics, mountain building (orogeny) and volcanic activity. The role of the Earth Sciences in society occupies 3 chapters which precede the cautionary tale of the Mohole project.

Why should such a text be reviewed in this journal? Because it provides an introduction to geology, a subject that should shortly expand to include the understanding of planets other than the Earth, for the techniques and theories developed from the study of the Earth will be of immediate application to other Earthlike planets (Venus, Mars). Kopal's article provides a synopsis of the composition of the lunar surface and he points out that debris from the surface of the Moon has a greater age (measured in thousands of millions of years) than the Earth's surface (measured in hundreds of millions of years). '..... an interpretation of the hieroglyphs engraved by Nature on her stony face holds a fascinating story as yet only partly unravelled! The chapter on the origin of life postulates that it is an inevitable consequence of an evolutionary process (and hence could take or have taken) place on any Earth-like planet. There are many instances of organized organic elements in meteorites — possibly prebiological cellular aggregates. Mason considers that, because a reducing environment favours the synthesis of organic compounds, '..... extraterrestrial life is more likely to be found on Saturn and Jupiter than it is on Mars and Venus'. The contamination of the lunar surface by terrestrial life will soon spread to Mars and Venus.

The catastrophic extinctions of various groups of plants and animals have been attributed to radiation from supernovae explosions or the radiation from the solar wind during the spilling of the Van Allen radiation belts as the polarity of the Earth's magnetic field reverses. Black shows that the ideas are not tenable and that another cause of faunal extinction must be sought.

We can apply knowledge gained on the Earth to other planets, with the probability of correct interpretations decreasing as the planetary conditions increase in dissimilarity with the Earth.

This text is a well written informative introduction, but one that includes several previously unpublished results.

Prof. J.S. GRIFFITH.

CORRESPONDENCE

Lagrange Points

Sir, In the very interesting article on Lagrange Points and Applications by T. Ransome [1], the writer has stated that 'At the L4 and L5 points.....probes could investigate the accumulated meteoric particles'.

While K. Kordylewski, Simpson and Miller of the Locksley Observatory, and others, have claimed to observe faintly luminous clouds at these points - which they interpreted as accumulated space debris - no such observations were made by J. R. Bruman during the lunar eclipse of 6 Oct. 1968 with the Schmidt telescope [2]. Several other observers also failed to identify these clouds of debris.

It seems surprising that Kordylewski could capture with a 35 mm camera what the Schmidt failed to see!

As N. Sekiguchi has pointed out [3], even if a cloud of matter is formed around a Libration Point, it will be very soon dispersed due to destabilising influences. There is thus no tendency for matter to accumulate at these points for any appreciable period. Scientists may have to write off the possibility of obtaining extremely ancient samples from these sites.

H. P. MAMA

REFERENCES

1. *Spaceflight*, 12, p.488. Dec. 1970.
2. Bruman, J. R., *Icarus*, 10, pp.197-200, 1969.
3. *The Moon*, 2, 2, Dec. 1970.

Questions of Time Travel

Sir, At least 2 popular works on Relativity [1,2] firmly dismiss as fallacious the notion that Time Dilation can result in a genuine (i.e. permanent) age difference between space travellers and those left on Earth. This suggests that the 'resolution' put forward by Professor Lawden *Spaceflight*, Aug. 1971, p.313, may not be as well known as all that; or that it is wrong, or perhaps that there is some other factor involved in the assumptions.

If there is indeed a permanent ageing effect, does it come from the space travellers' high velocity relative to Earth?; or from the initial acceleration needed to achieve that high velocity (the acceleration which makes the space traveller a non-inertial observer)? Is the space traveller a non-inertial observer when he has completed his initial acceleration and is travelling at constant velocity relative to the Earth? Does his ageing rate change when he stops accelerating? Is the space traveller any more of a non-inertial observer than we are when he accelerates at exactly one Earth 'g'?; suppose he does his whole journey (except launch and landing) accelerating at exactly one 'g', will his age on returning to Earth then be the same as if he had stayed at home? Suppose he does the whole journey at less than one 'g'? What happens if he does his accelerating in a centrifuge and doesn't actually travel anywhere at all?

K. HECKS

REFERENCES

1. Carr, L.H.A., 'Relativity for Engineers and Science Teachers', MacDonald, 1960. (p.47; a short section entitled 'The Youthful Traveller Fallacy').
2. Coleman, J. A., 'Relativity for the Layman', Penguin, 1959, (p.70-72).

Space Slides

Sir, May I offer some assistance to Mr. Humphreys (*Spaceflight*, Aug. 1971) and other members seeking a source of 35 mm slide material. Space slides covering the American Space Programme from the Gemini flights to the Apollo 14 mission may be obtained from Space Photos 2608 Sunset Blvd., Houston, Texas 77005, USA.

These slides are of excellent quality and each is well described.

The company also market a series of flying model rocket kits (including one which has a camera attached for taking aerial photographs).

R. HYSOON

(A series of 10 35 mm space film strips, is obtainable from Visual Publications Ltd., 197 Kensington High Street, London, W.8. They can easily be converted into slides at a very modest cost and be much cheaper than buying ready made slide sets. -Ed.)

Sun Probe

Sir, The most important star of concern to mankind over the next century is not 4.3 light years away, but 8.3 light minutes away.

Study of the Sun and its extensive environment of electromagnetic and corpuscular radiation ranks with interplanetary, and in due course, interstellar flight as a continuing objective in space exploration. This emphasis is changing from partial to substantial with the Helios solar probe programme now being conducted jointly by the U.S. and the Federal Republic of Germany.

S. W. GREENWOOD

Interstellar or Interplanetary?

Sir, The recent correspondence on renaming the BIS the British Interstellar Society overlooks the fact that the word 'Interplanetary' is usually interpreted to mean travel between the planets of our Solar System. However, when interstellar flight becomes possible it is most unlikely that we shall visit a star itself, but rather one or more of the planets orbiting that star.

Thus, the word 'Interplanetary' in the title of our Society will still be justified even in the interstellar age.

D. F. A. EDWARDS

NEXT MONTH

On the eve of the departure of Apollo 16 to Descartes, a central highland region of the Moon, the March issue of 'Spaceflight' will review the history of the Moon in the light of space exploration and examine in more detail the fascinating Hadley Rille site of the previous Apollo landing. We shall also preview the next important event in interplanetary exploration - the Pioneer probes to Jupiter.

We shall also be publishing the second instalment of the Table listing all man-made objects on the lunar surface, compiled by Geoffrey Falworth.

VIEWPOINT

Problems Solved

A programme based on Mr. Cross's article [1] for our departmental computing facility has been written by Miss Sara Davies and we are currently using it to evaluate various forms of help which the computer is able to give to the clinician. I mention this to show how an apparently esoteric set-up can be used to provide some practical information concerning the man-machine relationship when clinicians and computers come into contact.

The programme will eventually be rather a sophisticated one in that it will be adaptive - i.e. you can have as much or as little help as you wish from the computer.

Dr. F.T. de DOMBAL

REFERENCE

1. 'Simulating a Lunar Landing', C. A. Cross, *Spaceflight*, 12, p. 395, 1970.

It is immensely encouraging to see safety advances in aeronautical and space research translated into automatic safety standards in the past 4 years with benefits beginning to be evident in comparative reductions of death and injury, even though numbers of vehicles and miles travelled continues to show a sharp rise.

Savings by preventing the useless waste of resources and people in motor vehicle crashes might be sublimated into space research. This is a reversal of the current trend to recommend cutting back on space research on the pretext that the funds could be better spent on earthly woes and environmental conservation. Surely, there are better ways of leaving this world than by vehicle collision.

JOHN P. STAPP

Knowing that my memory is fallible at the best of times, I should be grateful if you would send me a blank Bankers Order form.

P. READ

Thank you for the not inconsiderable effort you must have expended to keep me 'satisfied'. Please accept the £1 donation as a tangible gesture of goodwill.....

DAVID W. PEACOCK

MILESTONES/continued from page 41]

December

- 1 Soviet Press gives first hint of final objectives of Mars 2. *Trud*: 'An artificial satellite of Mars, without touching down on its surface, is able to make a general evaluation of the nature of Martian minerals.' TV 'eye' will be able to discover objects of hundreds or even tens of metres in size. Instruments can also examine composition and properties of the planet's atmosphere and find the temperature on the day and night sides, etc. *Izvestia* quotes Lev Mukhin, chief of Laboratory of Exobiology of Institute of Space Research, as saying that no biological experiments were being made as this task is too complex to be attempted at the present stage of exploration.
- 2 Mars 3 releases capsule during final approach to Mars which 'entered the planet's atmosphere, parachuted down and soft-landed' in the Southern Hemisphere between *Electris* and *Phaetonis* (45°S, 158°W). Signals from capsule received and recorded aboard Mars 3 parent which achieved Mars orbit following final course-corrective and braking manoeuvres carried out automatically. Recorded signals from lander transmitted to Earth on 2 and 5 December, but 'video signals received from surface of Mars were brief and suddenly discontinued'.
- 2 Luna 19 at 17.00 hrs. (Moscow time) completes 722 revolutions of Moon; stable communications being maintained and scientific information telemetered to Earth. After 2 manoeuvres on 26 and 28 November respectively, orbit is 77 by 385 km, inclination to lunar equator 40°41', and period 2 hrs. 11 min.
- 2 Soviets launch Intercosmos 5 in joint experiment with Czechoslovakia, continuing research begun with Intercosmos 3 (launched August 1970) into radiation in near-Earth space, dynamics of corpuscular flux, and nature and spectrum of low-frequency electromagnetic oscillations in natural plasma. Orbit ranges between 202 and 1200 km inclined at 48.5° to equator, period 98.5 min.
- 3 Joint group of NASA and European Space Conference technical experts charged with identification of candidate areas for possible European participation in post-Apollo space programmes completes its work. Group identified several areas where definition and development activity could be undertaken in Europe. These include: sub-systems of the space shuttle; major responsibility for an orbit-to-orbit space tug; early development of major payload elements such as 'sortie cans' and research and applications modules; and supporting studies in related technology areas. The agreed report of the joint expert group 'will be considered by governmental authorities on both sides'.
- 5 French 3-stage Diamant B launched from Kourou, French Guiana, at 16.20 hrs. GMT fails to orbit D-2A (Polaire) satellite designed to study Earth's magnetic field from near-polar orbit. Solid-propellant second stage 'stopped burning' some 22 sec. early. First launch failure in CNES national satellite programme.
- 7 The following communique is released in Moscow jointly by NASA and the USSR Academy of Sciences: 'The third in a series of meetings on the design and testing of compatible space docking systems has been concluded successfully in Moscow by specialists of the Academy of Sciences of the USSR and the US National Aeronautics and Space Administration. Progress was made toward completing the definition of technical requirements for compatible systems in future spacecraft, as well as in planning possible joint test missions, the first of which could link an Apollo-type spacecraft and a Salyut-type space station'.

THE BRITISH INTERPLANETARY SOCIETY

LIMITED (by guarantee)

12 Bessborough Gardens London SW1V 2JJ (Tel. 01-828 9371)

ROCKET PROPULSION AND SPACE TRANSPORTATION

To be held at the Botany Lecture Theatre, University College,
Gower Street, London, W.C.1

18th-19th April, 1972.

LIST OF PAPERS

A Nuclear Rocket for the Space Tug by A. Bond (Rolls Royce).

Minimum Payload Using Ion + Chemical Stages: Soft-Landing from Spiral Orbits by D. S. Carton (Consultant).

A Comparative Review of Colloid and Iron Motors and their Space Applications by G. W. Childs (HSD).

Solid Propellant Combustion Instability by J. Gittins (R.P.E.).

Rocket Propulsion and Space Transportation by D. G. Humphries (HSD).

A Comparison of Argon and Mercury Propelled Ion Engines by A. R. Martin (City University).

Design Aspects of Low Power High Temperature Resistojets for Satellite Attitude Control by Dr. P. J. Musgrove (Univ. of Reading).

The Use of Mixed-Thruster Electric Propulsion with the Thor-Delta 2910 as a Launcher for Large Communications Satellites by Dr. R. C. Parkinson (R.P.E.).

The Development of the Waxwing Motor for Black Arrow by Dr. J. A. Rolfe (R.P.E.).

Research & Application Modules: Status & Trends by Dr. D. J. Shapland (ESRO).

Hydrazine Thrusters for Space Application by Dr. D. Sutton (R.P.E.).

Environmental Facility for Measurements of Low Thrust Ammonia Resistojets. (Provisional.) (Univ. of Southampton).

Theoretical Performance of Ammonia, Hydrazine and Biowaste Resistojets (Provisional.) (Univ. of Southampton).

One-Dimensional Flow Model for an Air-Augmented Rocket (Provisional.) (Univ. of Southampton).

Laser Measurements of Turbulence in Exhaust Jets (Provisional.) (Univ. of Southampton).

Other Papers in Course of Arrangement

Solid Propellant Rocket Development.
Lifting Body Aerodynamics.

Registration forms are available from the Executive Secretary on request.

SCOPE OF CONTRIBUTIONS

1. Main Papers

For reading at the meeting with a presentation time of between 20-30 min., plus questions. These Papers are normally published in the Society's *Journal*.

2. Associated Papers

Authors who are precluded by reason of distance or other matters from attending personally, may also contribute a written MSS, to be submitted (with preprints if desired) and published as part of the Proceedings of the Meeting.

3. Short Papers/Reports

Short papers may be presented (up to 10 min. duration) on aspects of particular interest which do not lend themselves to presentation as Main Papers, e.g. Research Reports, Current News, or other Statements of Interest. Notice of presentation must be given in good time to allow for incorporation in the final programme.

4. Registration

Registration is necessary for all Main Meetings. Registration Forms are obtainable from the Executive Secretary on request.

OTHER FORTHCOMING MAIN MEETINGS

Title	Venue	Date
(a) 12th European Space Symposium	Venice, Northern Italy	Mid-June 1972
<i>Theme</i> "Control & Guidance of Space Vehicles".		
(b) The Satellites UK4 and Prospero-Scientific Results and Technology	University College, London, W.C.1.	27 Sep. 1972
(c) Communications Satellites	University of Southampton.	29-30 Sep. 1972.
(d) The Management of Space Projects	Royal Society of Arts, London, W.C.2.	14 Nov. 1972
(e) The Exploration of Deep Space	Royal Society of Arts, London, W.C.2.	18 Dec. 1972
(f) Studies of the Moon - A Synthesis of Recent Discoveries	Royal Society of Arts, London, W.C.2.	Early 1973
(g) Structures of Space Vehicles and Spacecraft	University College, London, W.C.1.	4 Apr. 1973
(h) Earth Observation Satellites	University College, London, W.C.2.	11 Apl. 1973
(i) Sounding Rockets & Experimental Results - 3	University College, London, W.C.2.	Sep. 1973

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: telephone 01-828 9371.

SPACE STUDY MEETING

The 10th Space Study Meeting will be held in the Kent Room, Caxton Hall, Caxton Street, S.W.1, on **10 February 1972** from 6.30–8.30 p.m.

The programme will be as follows:

- (a) Highlights of the Apollo 15 Cape Kennedy Visit by M. F. Allward.
- (b) Arrangements for an Apollo 16 excursion

APOLLO 16 LIFT-OFF, 12-21 March 1972

The Society, in association with Transolar Travel Ltd., is arranging a Special Charter Flight for Members and Guests to see the Apollo 16 lift-off.

A special excursion will be made by a Boeing 707, leaving Gatwick Airport for a direct flight to Melbourne, Florida, with coaches meeting the flight to complete the short journey to Cocoa Beach.

Accommodation will be provided at a Luxury Motel for eight nights.

A comprehensive coach tour of the Space Facility will be made, including a visit to the Vertical Assembly Building and Launch Complex 39.

The total cost of flight and accommodation, excluding meals, is £128. Please apply quickly if you wish to go: most of the places have now gone.

Further information and booking forms are available from The Executive Secretariat, British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

FILM SHOW

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1 on **5 April 1972**, 6.30–8.30 p.m.

The Programme will provide a second opportunity to see a number of outstanding films, i.e.:

- (a) Returns from Space.
- (b) The Moon – Old and New.
- (c) Apollo 15: The Mountains of the Moon.
- (d) Voyages to the Planets.

No admission tickets needed. Members may introduce guests.

MAIN MEETING

Theme **Rocket Propulsion and Space Transportation**
To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1 on **18-19 April 1972**.

Subject areas are as follows:

- (a) Ground Test Facilities
- (b) High Energy Propulsion
- (c) Solid Propellants
- (d) Thrust Vector Control
- (e) Rocket Plumes (Flame Physics)
- (f) Instrumentation Techniques
- (g) Advanced Propulsion.
- (h) Space Shuttle Technology, which will also include Associated Systems. Subject areas are as follows:

- | | |
|--------------------------|--------------------------|
| (a) Re-entry | (g) Space Stations |
| (b) Lifting Body | (h) Structures |
| (c) Aerodynamics | (i) Propulsion |
| (d) Heat Transfer | (j) Guidance and Control |
| (e) Refractory Materials | (k) Mission Analysis |
| (f) Design Studies | (l) Cost Effectiveness |
| (g) Space Tug | |

Offers of papers are invited.

Further details appear on the inside cover of this issue.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12 Bessborough Gardens, London, SW1V 2JJ

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

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27th ANNUAL GENERAL MEETING

The 27th Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on **14 June 1972** at 6.30 p.m.

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed, signed and returned not later than 3 June 1972.

If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members before the date of the meeting.

12th EUROPEAN SPACE SYMPOSIUM

To be held at a venue in Northern Italy over a 3-day period in **mid-June, 1972**

Theme **Control and Guidance of Space Vehicles**

Members interested in participating and for presenting papers are invited to communicate with the Executive Secretary.

MAIN MEETING

Theme **Communications Satellites**

To be held at the University of Southampton on **19-20 September 1972**.

Subject areas are as follows:

- (a) Regional Satellites
- (b) Aeronautical and Maritime Satellites
- (c) Review of Present Systems
- (d) Transmission of Digital Data
- (e) Information Storage and Retrieval
- (f) Operations Experience
- (g) Educational (TV) Satellites.
- (h) Power Supplies.
- (i) Ground Stations.

Offers of papers are invited.

Further details are available from the Executive Secretary.

APOLLO 17 LIFT-OFF DECEMBER 1972

The Society, in association with Transolar Travel Ltd, is arranging for members and guests to witness the Apollo 17 lift-off. This will be the last of the American manned missions to the Moon, using the giant Saturn V rocket. It will be an historic moment.

Those interested are invited to make *early* reservations. Reservation forms and other details can be obtained on request

ADVANCE NOTICE OF FUTURE MEETINGS

Offers of papers for presentation at the following Main Meeting of the Society, now being organised, will be welcomed.

Further details are available from the Executive Secretary on request.

- (a) Structure of Space Vehicles and Spacecraft.
- (b) Sounding Rockets and Experimental Results – 3.
- (c) Earth Observation Satellites.
- (d) Management of Space Projects.

Papers are also invited for presentation at the following General Meetings, now being organised:—

- (e) Studies of the Moon – A Synthesis of Recent Discoveries.
- (f) The Exploration of Deep Space.
- (g) Satellites Ariel 4 and Prospero.